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Association Between Hypertension in Pregnancy and Neonatal Head Circumference at Dr. Moewardi Hospital, Surakarta, Central Java, Indonesia

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ABSTRACT

Background: Hypertension during pregnancy remains a major obstetric complication that contributes significantly to maternal and perinatal morbidity and mortality. This condition may lead to uteroplacental insufficiency, resulting in impaired fetal growth and development. Neonatal head circumference is commonly used as an indicator of intrauterine brain growth; however, evidence regarding its association with hypertension in pregnancy is still limited. This study aimed to evaluate the relationship between hypertension in pregnancy and neonatal head circumference at Dr. Moewardi Hospital, Surakarta.

Subjects and Method: This was a cross-sectional study conducted at Dr. Moewardi Hospital, Surakarta, Indonesia. The study included 80 mother–newborn pairs selected using purposive sampling from medical records between 2023 and 2025. The independent variable was hypertension in pregnancy. The dependent variable was neonatal head circumference. Data were analyzed using the chi-square test and presented as odds ratios (OR), 95% confidence intervals (CI), and p-values.

Results: There was no significant association between hypertension in pregnancy and neonatal head circumference (OR = 1.485; 95% CI = 0.429 to 5.143; p = 0.531). High BMI was significantly associated with hypertension in pregnancy (OR= 4.636; p = 0.003).

Conclusion: Hypertension in pregnancy was not significantly related to neonatal head circumference. However, maternal nutritional status was significantly associated with hypertension in pregnancy.

Keywords: gestational hypertension, neonatal head circumference, maternal nutritional status

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BACKGROUND

Hypertension is defined as a chronic condition characterized by persistently elevated blood pressure above normal values, resulting in increased cardiac workload and vascular wall stress. During pregnancy, it is diagnosed when blood pressure reaches ≥140/90 mmHg and is associated with a higher risk of adverse maternal and neonatal outcomes (Febriyani, 2021).

Hypertension in pregnancy affect approximately 6–10% of pregnancies worldwide and contribute significantly to maternal and perinatal morbidity and mortality. Maternal complications may include placental abruption, disseminated intravascular coagulation (DIC), stroke, and organ failure, while fetal complications include intrauterine fetal death, intrauterine growth restriction (IUGR), low birth weight, and preterm birth (Syam et al., 2023). Globally, an estimated 33% of adults aged 30–79 years have hypertension (WHO, 2025).

In Indonesia, data from the National Basic Health Research (Ministry of Health of the Republic of Indonesia, 2018) report a hypertension prevalence of 34.1%. Hypertension in pregnancy remains one of the leading causes of maternal mortality, accounting for 412 of 4,482 maternal deaths in 2023 based on the National Health Profile (Ministry of Health of the Republic of Indonesia, 2024). Dr. Moewardi Hospital in Central Java serves as a referral center and manages a substantial number of high-risk pregnancies, including those complicated by hypertension.

The pathophysiology of hypertension in pregnancy involves vasospasm and impaired remodeling of uteroplacental arteries, resulting in reduced placental perfusion and impaired oxygen and nutrient supply to the fetus. This condition may disrupt intrauterine brain development and affect neonatal head circumference at birth (Faadhilah & Helda, 2020).

Fetal growth disturbance is one of the major consequences of maternal hypertension and can be assessed through neonatal anthropometric parameters such as birth weight, body length, and head circumference. Among these parameters, head circumference reflects brain growth and serves as an important indicator of early neurodevelopment. Compared to other anthropometric measures such as birth weight and body length, it provides a more specific representation of brain development, whereas birth weight reflects overall fetal growth and may be influenced by factors such as fluid status and fat accumulation.

Recent evidence demonstrates that head circumference at birth is associated with long-term cognitive and academic outcomes. A large population-based cohort study reported that smaller head circumference at birth was associated with lower academic performance during school age, although the effect size at the individual level may be modest (Bach et al., 2020). Furthermore, head circumference has been shown to correlate with total brain volume measured using neuroimaging techniques and with neurodevelopmental outcomes, including cognitive and motor function (Selvanathan et al., 2022). Longitudinal studies have shown that head circumference is associated with cognitive, language, and motor development during early childhood (Nicolaou et al., 2020; Mayrink et al., 2024).

Collectively, these findings suggest that neonatal head circumference is a reliable indicator of brain growth and neurodevelopmental outcomes. Compared to other anthropometric measures, it provides a more specific reflection of brain development. Therefore, it represents a more sensitive and clinically relevant parameter for evaluating the impact of intrauterine conditions, including maternal hypertension, on early-life brain development. For this reason, neonatal head circumference was selected as the primary outcome in this study.

Abnormal head circumference may indicate microcephaly (<−2 SD) or macrocephaly (> +2 SD), both of which are associated with adverse neurodevelopmental outcomes (CDC, 2023; Jones et al., 2023). Previous studies by Hudayah et al. (2023) and Winarsih (2024) have also reported an association between hypertension in pregnancy and impaired fetal growth, including reduced head circumference.

However, data regarding the association between hypertension in pregnancy and neonatal head circumference in this population remain limited. Therefore, this study aims to examine the association between hypertension in pregnancy and neonatal head circumference at Dr. Moewardi Hospital. The study is expected to contribute to improving maternal and neonatal healthcare quality.

SUBJECTS AND METHOD

1. Study Design

This study utilized an analytic observational design with a cross-sectional approach based on retrospective data obtained from medical records at Dr. Moewardi Hospital, Surakarta, covering the period from January 2023 to December 2025.

2. Populationand Sample

The target population comprised all mothers and their newborns who delivered at Dr. Moewardi Hospital. The source population included those with complete medical records data during the study period. The minimum sample size was calculated using the Lemeshow formula, resulting in 73 subjects. To anticipate incomplete data, a total of 80 mother–newborn pairs were included using purposive sampling.

3. Study Variables

The independent variable was hypertension in pregnancy. The dependent variable was neonatal head circumference. Potential confounding variables included maternal age, gestational age, parity, maternal nutritional status, infant sex, and birth weight.

4. Operational Definition of Variables

Hypertension in pregnancy was defined as blood pressure ≥140/90 mmHg measured at least twice with a minimum interval of four hours during pregnancy, with or without proteinuria, the condition was categorized as a dichotomous variable (hypertension or no hypertension) without further classification into specific subtypes.

Neonatal head circumference was measured from the most prominent part of the forehead (glabella) to the most prominent part of the occiput and classified based on the Lubchenco growth chart into appropriate for gestational age (AGA) or abnormal (small or large for gestational age).

Maternal age was defined as the age of the mother at delivery, calculated from the date of birth to the date of delivery, and categorized into ≤30 years and >30 years.

Parity was defined as the number of prior live births and categorized into primipara (1 birth), multipara (2–4 births), and grand multipara (≥5 births).

Gestational age was defined as the duration of pregnancy calculated from the first day of the last menstrual period to delivery and categorized as term (37–42 weeks) or non-term (<37 or >42 weeks).

Maternal nutritional status was assessed based on pre-pregnancy body mass index (BMI), calculated as weight (kg) divided by height squared (m^2), and categorized as underweight (<18.5), normal (18.5–24.9), or overweight/obese (≥25).

Infant sex was defined as recorded in the medical records and categorized as male or female.

Birth weight was defined as the newborn's weight measured within one hour of birth using a calibrated scale and categorized as normal (2500–3999 g), low birth weight (<2500 g), or macrosomia (≥4000 g).

5. Study Instruments

Data were obtained from medical records of mothers and newborns at Dr. Moewardi Hospital, including information on maternal hypertension status, neonatal head circumference, and perinatal characteristics. No primary data collection was performed.

6. Data Analysis

SPSS software was used for data analysis. Sample characteristics were described using univariate analysis, while bivariate associations were examined using the chi-square test. Odds ratios with 95% confidence intervals and p-values were presented. Multivariate analysis was not performed due to limited outcome events and sparse data, which could produce unstable estimates.

7. Research Ethic

The study adhered to ethical principles of health research. Participant confidentiality and anonymity were strictly preserved. Ethical approval was granted by the Research Ethics Committee of Dr. Moewardi Hospital, Surakarta, Indonesia (No. KEPK/RSUDMW/2025/045; issued on August 15, 2025.

RESULTS

1. Sample Characteristics

The study included 80 mother–newborn pairs. Maternal age had a mean of 31.39 ± 5.34 years (range 22–46 years), while gestational age averaged 38.51 (SD= 1.29 weeks, range 37–41 weeks). Table 1 presents the characteristics of the continuous variables.

Table 1. Sample characteristics (continous data)

Variables	Mean	SD	Min.	Max.
Maternal age (years)	31.39	5.34	22	46
Gestational Age (weeks)	38.51	1.29	37	41

Based on categorical variables, the proportion of mothers with and without hypertension in pregnancy was equal (50.0% each). Most mothers had abnormal nutritional status (70.0%), while 30.0% had normal body mass index. Slightly more than half of the mothers were aged >30 years (52.5%), while 47.5% were ≤30 years.

All pregnancies were term (100.0%), with no cases of preterm or postterm delivery. In terms of parity, 56.3% of mothers were multiparous or grand multiparous, while 43.8% were primiparous.

The distribution of infant sex was relatively balanced, with 51.3% male and 48.8% female. Most infants had normal birth weight (93.8%), while 6.3% had abnormal birth weight (low birth weight or macrosomia). Similarly, the majority of infants had normal head circumference (85.0%), while 15.0% were categorized as abnormal (small or large for gestational age). The characteristics of categorical variables are presented in Table 2.

Table 2. Sample characteristics (categorical data)

Characteristics	Category	Frequency	Percentage
Hypertension	No Hypertension	40	50.0%
	Hypertension	40	50.0%
Maternal Nutritional	Normal	24	30.0%

Characteristics	Category	Frequency	Percentage
BMI	Abnormal (overweight / underweight)	56	70.0%
Maternal Age	≤ 30 Years	38	47.5%
	> 30 Years	42	52.5%
Gestational Age	Term	80	100.0%
	Preterm / Postterm	0	0.0%
Parity	Primiparous	35	43.8%
	Multiparous / Grand multiparous	45	56.3%
Infant Sex	Male	41	51.3%
	Female	39	48.8%
Birth Weight	Normal	75	93.8%
	Abnormal (LBW / Macrosomia)	5	6.3%
Head Circumference	Normal (AGA)	68	85.0%
	Abnormal (SGA / LGA)	12	15.0%

2. Bivariate analysis

The relationship between maternal and neonatal factors and neonatal head circumference as well as hypertension in pregnancy was analyzed using bivariate methods. The findings are shown in Tables 3 and 4.

The analysis of factors associated with neonatal head circumference (Table 3) showed that hypertension in pregnancy showed no significant association with neonatal head circumference (OR= 1.485; 95% CI= 0.429 to 5.143; p= 0.531). Similarly, maternal nutritional status based on body mass index was not significantly associated (OR = 0.833; 95% CI = 0.225 to 3.084; p = 0.785).

Maternal age (OR = 0.889; 95% CI = 0.260 to 3.034; p = 0.851), parity (OR = 0.744; 95% CI = 0.217 to 2.542; p = 0.636), infant sex (OR = 2.387; 95% CI = 0.656 to 8.686; p = 0.178), and birth weight (OR = 1.455; 95% CI = 0.148 to 14.260; p = 0.746) were also not significantly associated with neonatal head circumference. There was no significant associations were observed among the variables analyzed (p > 0.05).

Table 3. Bivariate analysis of factors associated with neonatal head circumference

Variables	Head Circumference				95% CI		OR	p
	Normal		Abnormal		Lower Limit	Upper Limit		
	n	%	n	%				
Hypertension								
No	35	87.5	5	12.5	0.42	5.14	1.48	0.531
Yes	33	82.5	7	17.5				
Maternal Nutritional Status (BMI)								
Normal	20	29.4	4	33.3	0.22	3.08	0.83	0.785
Abnormal	48	70.6	8	66.7				
Maternal Age								
≤ 30 Years	32	47.1	6	50	0.26	3.03	0.88	0.851
> 30 Years	36	52.9	6	50				
Parity								
Primiparous	29	42.6	6	50	0.21	2.54	0.74	0.636

Variables	Head Circumference				95% CI		OR	p
	Normal		Abnormal		Lower Limit	Upper Limit		
	n	%	n	%				
Multiparous / Grand multiparous	39	57.4	6	50				
Infant Sex								
Male	37	54.4	4	33.3	0.65	8.68	2.38	0.178
Female	31	45.6	8	66.7				
Birth Weight								
Normal	64	94.1	11	91.7	0.14	14.26	1.45	0.746
LBW / Macrosomia	4	5.9	1	8.3				

In contrast, the analysis of factors associated with hypertension in pregnancy (Table 4) showed that maternal nutritional status was significantly associated with hypertension. The risk of hypertension in pregnancy was higher among mothers with abnormal body mass index than among those with normal body mass index (OR= 4.64; 95% CI= 1.59 to 13.49; p= 0.003).

Birth weight was also significantly associated with hypertension in pregnancy (OR= 1.14; 95% CI= 1.01 to 1.29; p= 0.021), although this finding should be interpreted cautiously because of limited data.

Maternal age (OR= 1.50; 95% CI= 0.62 to 3.61; p= 0.370), parity (OR = 0.82; 95% CI= 0.34 to 1.97; p= 0.653), and infant sex (OR= 1.10; 95% CI= 0.46 to 2.66; p= 0.823) showed no statistically significant association with hypertension in pregnancy (p > 0.05).

Table 4. Bivariate analysis of factors associated with maternal hypertension

Variables	Hypertension				95% CI		OR	p
	No		Yes		Lower Limit	Upper Limit		
	n	%	n	%				
Maternal Nutritional Status (BMI)								
Normal	18	45.0	6	15.0	1.59	13.49	4.63	0.003
Abnormal	22	55.0	34	85.0				
Maternal Age								
≤ 30 Years	21	52.5	17	42.5	0.61	3.61	1.49	0.370
> 30 Years	19	47.5	23	57.5				
Parity								
Primiparous	17	42.5	19	47.5	0.33	1.97	0.81	0.653
Multiparous / Grand multiparous	23	57.5	21	52.5				
Infant Sex								
Male	21	52.5	20	50	0.46	2.65	1.10	0.823
Female	19	47.5	20	50				
Birth Weight								
Normal	40	100	35	87.5	1.01	1.28	1.14	0.021
LBW / Macrosomia	0	0	5	12.5				

DISCUSSION

1. Characteristics of Study Subjects

The study involved 80 mother–newborn pairs, with an equal distribution between mothers with hypertension in pregnancy and those without (50% each). Most mothers had abnormal nutritional status (70%), predominantly classified as overweight or underweight. The mean maternal age was 31.39 (SD 5.34 years), with a slightly higher proportion of mothers aged over 30 years. All deliveries occurred at term gestation, with a mean gestational age of 38.51 (SD= 1.29 weeks). The majority of mothers were multiparous or grand multiparous.

Regarding neonatal characteristics, the distribution of infant sex was relatively balanced. Most newborns had normal birth weight and normal head circumference, with only a small proportion classified as having abnormal head circumference.

The homogeneity in gestational age observed in this study is likely attributable to the inclusion and exclusion criteria, which restricted the sample to term pregnancies by excluding preterm and post-term deliveries. This design was intended to minimize the confounding effect of gestational age on neonatal outcomes. However, the resulting limited variability may have reduced data dispersion and statistical power, thereby decreasing the ability to detect significant associations between maternal factors and neonatal head circumference. In addition, this homogeneity limits the generalizability of the findings to populations with a broader range of gestational ages, particularly preterm or high-risk pregnancies.

2. The Relationship between Hypertension in Pregnancy and Neonatal Head Circumference

Hypertension in pregnancy can interfere with the remodeling of uteroplacental vessels, resulting in decreased placental perfusion. This condition may decrease oxygen and nutrient delivery to the fetus and potentially disrupt intrauterine growth, including brain development, thereby affecting neonatal head circumference (Torres-Torres et al., 2024). However, as a compensatory mechanism, the fetus may activate the brain-sparing effect, which redistributes blood flow to vital organs, particularly the brain, to preserve cerebral perfusion despite placental insufficiency (Benítez-Marín et al., 2021). Consequently, the effect of maternal hypertension on neonatal head circumference may not always be directly observable.

In the present study, all pregnancies were term, and hypertension in pregnancy was not significantly associated with neonatal head circumference ($p = 0.531$). This finding may indicate that fetal cranial growth remains relatively preserved in term pregnancies; however, it may also reflect the limited variability of the sample and methodological constraints.

This result is consistent with Defanty (2020), who reported no significant association between preeclampsia and neonatal head circumference ($p = 0.389$), although a significant relationship was observed with birth weight. Similarly, Hao et al. (2021) found that while birth weight and body length differed significantly between hypertensive and normotensive pregnancies ($p < 0.05$), there was no statistically significant difference in neonatal head circumference ($p > 0.05$). These results imply that hypertension in pregnancy may have a greater impact on overall fetal growth rather than specifically on cranial growth.

In contrast, de Moura et al. (2021), in a study involving preterm infants, reported significantly smaller head circumference among infants born to hypertensive mothers ($p < 0.001$), accompanied by a greater risk of being small for gestational age. Similarly, Irwinda et al. (2016) found significantly lower birth weight, body length, and head circumference in infants of mothers with pregnancy-induced hypertension ($p < 0.001$).

These discrepancies may be primarily explained by variations in gestational age and participant characteristics. Studies involving preterm or high-risk pregnancies tend to demonstrate a stronger association between maternal hypertension and impaired fetal growth, whereas in term pregnancies, compensatory mechanisms such as the brain-sparing effect may help preserve fetal cranial development.

In addition, several methodological factors may explain the non-significant findings in this study. First, all subjects were restricted to term pregnancies, which may have reduced variability in neonatal outcomes and limited the ability to detect significant differences. In term pregnancies, compensatory mechanisms may help preserve fetal brain growth despite impaired placental perfusion. Second, the relatively low proportion of neonates with abnormal head circumference (15%) may have limited the statistical power and increased the possibility of a Type II error. Third, hypertension in pregnancy was analyzed as a dichotomous variable without classification into severity or subtypes, which may have obscured potential differences between mild and severe conditions.

Furthermore, the use of purposive sampling and inclusion of only cases with complete medical records may introduce selection bias. This approach may have excluded more severe or complicated cases, leading to a more homogeneous study population and potentially underestimating the true effect of hypertension in pregnancy on neonatal head circumference.

Overall, the findings indicate that hypertension in pregnancy was not significantly associated with neonatal head circumference in this study population. This suggests that fetal cranial growth may be relatively preserved in term pregnancies, although it is likely influenced by multiple factors, including gestational age, severity of hypertension, maternal nutritional status, quality of antenatal care, and genetic determinants. Further studies with larger sample sizes and stratification by severity of hypertensive disorders are warranted to clarify this relationship.

3. The Relationship Between Other Factors and Neonatal Head Circumference

In addition to maternal hypertension, several maternal and neonatal factors including maternal age, gestational age, maternal nutritional status, parity, infant sex, and birth weight were evaluated as potential confounders due to their established roles in fetal growth and intrauterine development. However, bivariate analysis demonstrated that none of these variables were significantly associated with neonatal head circumference (all $p > 0.05$).

Maternal age is theoretically associated with fetal growth, particularly at the extremes of reproductive age. Previous studies have reported a positive correlation between maternal age and neonatal anthropometric parameters, including head circumference (Di Gravio et al., 2019). However, no significant association was observed in this study ($p = 0.851$), which may be attributed to the relatively homogeneous distribution of maternal age within the normal reproductive range, thereby limiting variability in fetal growth outcomes. Similar findings have been reported by Kirchweger et al. (2018), suggesting that maternal age within the normal range may not be a strong independent determinant of neonatal head circumference.

Gestational age plays a crucial role in fetal growth, particularly during the third trimester when brain development accelerates. However, this variable could not be meaningfully analyzed in the present study because all subjects were term pregnancies. The lack of variability in gestational age may have limited its contribution to differences in neonatal head circumference.

Maternal nutritional status, assessed using BMI, showed no meaningful relationship with neonatal head circumference (p = 0.833). While maternal BMI has been consistently linked to overall fetal growth, particularly birth weight, its relationship with head circumference appears less consistent. Some studies suggest that only extreme nutritional conditions significantly affect cranial growth (Syböck et al., 2023), indicating that the impact of maternal BMI may depend on the severity of nutritional imbalance and population characteristics.

Parity showed no meaningful relationship with neonatal head circumference (p = 0.636). Although multiparity has been associated with improved uterine adaptation and potentially larger fetal size, evidence regarding its influence on head circumference remains inconsistent across studies, suggesting that its effect may be mediated by other maternal or environmental factors.

Infant sex also showed no statistically significant association (p = 0.178), although male infants had higher odds of abnormal head circumference. Biologically, male neonates tend to have slightly larger anthropometric measurements; however, these differences are generally small and may not reach statistical significance, particularly in studies with limited sample size.

Similarly, birth weight showed no meaningful relationship with neonatal head circumference (p = 0.746), despite being a commonly used indicator of fetal growth. This finding may be influenced by the low proportion of abnormal birth weight cases in the study population. Prior research has identified a positive relationship between birth weight and head circumference (Basnet et al., 2025), such an association was not evident in this study, possibly due to limited variability in both parameters and the low proportion of abnormal outcomes.

The absence of significant associations across these variables may reflect both biological and methodological factors. Biologically, neonatal head circumference may be relatively preserved due to mechanisms that prioritize brain development, particularly in term pregnancies. Methodologically, the relatively homogeneous sample, characterized by term gestation and predominantly normal neonatal outcomes, may have reduced variability and limited the ability to detect meaningful differences. In addition, the use of purposive sampling and inclusion of only cases with complete medical records may have introduced selection bias, potentially excluding more severe or high risk cases. These factors could have attenuated the observed associations and should be considered when interpreting the findings.

Overall, these findings suggest that neonatal head circumference in this study population may be relatively preserved due to limited variability and influenced by multifactorial mechanisms rather than a single determinant.

4. Risk Factors for Hypertension in Pregnancy

In addition to neonatal outcomes, this study examined several maternal and neonatal factors associated with hypertension in pregnancy. The results showed that maternal nutritional status was significantly associated with hypertension, while maternal age, parity, and infant sex were not. Birth weight, as a neonatal outcome, was also significantly associated with maternal hypertension.

Maternal nutritional status was a significant risk factor for hypertension in pregnancy. Mothers with abnormal BMI were 4.6 times more likely to develop hypertension in pregnancy than those with normal BMI (OR = 4.636; p = 0.003). This finding is consistent with previous studies showing that both undernutrition and overnutrition contribute to hypertensive disorders through mechanisms involving endothelial dysfunction, systemic inflammation, and oxidative stress (Kinshella et al., 2022; Magee et al., 2022). While undernutrition may impair placental development and uteroplacental perfusion, obesity is associated with chronic inflammation, insulin resistance, and activation of the renin–angiotensin system, all of which contribute to a higher likelihood of hypertension in pregnancy. However, despite its significant association with hypertension, maternal nutritional status was not significantly associated with neonatal head circumference, suggesting that its effect may be more pronounced on maternal vascular outcomes than on fetal cranial growth.

Maternal age showed no significant association with hypertension in pregnancy (OR= 1.495; p = 0.370). Although advanced maternal age is a recognized risk factor due to vascular and metabolic changes, this association was not observed, likely due to the relatively homogeneous age distribution within the reproductive range. Previous studies have shown that the risk becomes more apparent at maternal age ≥35 years (Yang et al., 2021).

Parity also showed no significant association with hypertension (OR = 0.817; p = 0.653). Primiparity is known to carry a higher likelihood of preeclampsia due to immunological and vascular adaptation; however, this pattern was not observed in the present study. This discrepancy may be influenced by sample size and the relatively balanced distribution of parity, which may have reduced the ability to detect differences between groups.

Infant sex showed no significant association with hypertension in pregnancy (OR= 1.105; p = 0.823). Although some evidence suggests slightly higher maternal blood pressure in pregnancies with male fetuses, the effect is generally minimal and lacks clinical relevance, suggesting a greater influence of maternal factors on the occurrence of hypertension.

A significant association was observed between birth weight and hypertension in pregnancy (p = 0.021), with hypertensive mothers more likely to deliver infants with abnormal birth weight. However, this finding should be interpreted with caution due to sparse data and the presence of zero cell frequencies, which may affect the stability of the estimates. From a biological perspective, hypertension may impair placental perfusion and lead to fetal growth restriction, which is reflected in abnormal birth weight. This finding is consistent with previous studies linking hypertension in pregnancy to adverse neonatal outcomes, particularly low birth weight (Wahabi et al., 2024).

Overall, these findings highlight maternal nutritional status as the most prominent modifiable risk factor for hypertension in pregnancy in this study population. The absence of significant associations for other variables may reflect both biological and methodological factors. The relatively homogeneous sample, particularly in terms of maternal age and parity distribution, may have reduced variability and limited the ability to detect meaningful differences. In addition, the use of purposive sampling and inclusion of only cases with complete medical records may have introduced selection bias, potentially exclude more severe or high-risk cases and lead to an underestimation of the true associations.

In conclusion, this study found no significant association between hypertension in pregnancy and neonatal head circumference among term pregnancies. However, maternal nutritional status was significantly associated with the development of hypertension in pregnancy, and hypertension was also related to abnormal birth weight. These findings suggest that neonatal head circumference may be relatively preserved in term pregnancies and influenced by multifactorial mechanisms rather than maternal hypertension alone. Clinically, this underscores the importance of routine nutritional assessment, dietary counseling, and blood pressure monitoring during antenatal care, as well as careful monitoring of fetal growth to ensure optimal neonatal outcomes.

Nevertheless, these findings should be interpreted with caution due to several limitations. The absence of multivariate analysis represents a major limitation of this study, as the relatively small number of abnormal head circumference cases and sparse data prevented further modeling and limited the ability to control for potential confounding variables. In addition, all subjects were restricted to term pregnancies, resulting in a lack of variability in gestational age. Given that gestational age plays a crucial role in fetal growth and brain development, this limitation may have reduced the ability to detect its effect on neonatal head circumference and limit the generalizability of the findings to preterm or high-risk populations. Furthermore, hypertension in pregnancy was analyzed as a dichotomous variable without classification into subtypes, which may have obscured differences between levels of severity. The use of secondary data from medical records and purposive sampling may also introduce information and selection bias, potentially excluding more severe or complicated cases. Therefore, future studies are recommended to include larger and more diverse populations, apply multivariate analysis, and incorporate classification of hypertensive disorders to better understand their impact on neonatal outcomes.

Study Limitation

Multivariate analysis was not performed in this study. Although one variable (infant sex) met the initial criterion for inclusion ($p < 0.25$), the number of abnormal neonatal head circumference cases was limited ($n = 12$).

In logistic regression analysis, it is generally recommended to have at least 10 outcome events for each independent variable to ensure stable parameter estimation. Given the limited number of outcome events, inclusion of multiple variables could result in model instability and overfitting.

In addition, several variables had small or zero cell frequencies, particularly birth weight, which may lead to unreliable estimates. Therefore, bivariate analysis was deemed appropriate for evaluating the relationships among the variables in this study.

AUTHOR CONTRIBUTION

Annisya Fitria was responsible for developing the study concept and design, performing data analysis, interpreting the findings, and preparing the initial manuscript draft. Andhika Trisna Putra and Irfan Dzakir Nugroho contributed to data analysis and provided critical revisions. All authors reviewed and approved the final version of the manuscript.

CONFLICT OF INTEREST

There are no conflict of interest.

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