Risk factors of neonatal mortality in Jember Regency, Indonesia: A case-control study

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ABSTRACT

Background: Neonatal mortality constitutes most infant deaths in Indonesia, influenced by maternal and infant factors, smoking exposure levels during pregnancy, and the seeking of health services.

Objectives: The study aimed to determine risk factors associated with neonatal mortality in Jember Regency.

Methods: This observational analytical study employed a case-control design, with 42 cases and 42 controls selected by simple random sampling. Data collection used a documentation study to obtain maternal and infant characteristics, and maternal cigarette smoke exposure level was assessed using a direct interview SHSES questionnaire.

Results: Mostly the age of mothers from case and control 20-35 years, gestational age 37-42 weeks, upper arm circumference ≥23.5 cm, not anemic, parity 2-4, experiencing complications, heavy exposure to cigarette smoke, birth spacing 24-60 months, birth weight <2500 & >4000 grams, inappropriate ANC, delivery assisted by health workers in health care facilities, and using the abdominal delivery method. Preterm and postterm delivery increased neonatal death risk 3.5 times (OR =3.511; 95% CI = 1.316-9.364), maternal or infant complications increased risk 4.2 times (OR = 4.200; 95% CI = 2.445-7.214), extreme birth weight increased risk 4.4 times (OR = 4.462; 95% CI = 1.785-11.154), and the vaginal delivery method is 0.194 times (OR = 0.194; 95% CI = 0.073-0.518) more protective than the abdominal delivery method.

Conclusions: Preterm and post-term birth, maternal and neonatal complications, extreme birth weight, and abdominal delivery were associated with neonatal mortality. Strengthening early risk detection and antenatal care quality to prevent complications, optimize birth outcomes, and improve referral coordination to support targeted neonatal mortality reduction strategies.

KEYWORD: antenatal care; birth weight; delivery; infanty mortality; obstetric

INTRODUCTION

The Infant Mortality Rate (IMR) remains a key indicator of a population's health and is generally used to reflect a community's health, as newborns are susceptible to environmental conditions closely related to their parents' social status. The World Health Organization 2022 stated that infant mortality was dominated by infant mortality in the neonatal phase of 17.3/1000 KH in 2022, with South Sudan at the highest ranked. (1,2) Nationally, neonatal mortality in Indonesia was recorded at 27,530 cases, or 80.4% of total infant mortality, in 2023, higher than in 2022, when it was 18,281 cases, or 75.5% of total infant mortality. (3,4)This issue must be addressed to achieve Indonesia's RPJMN 2024 target of 16/1000 KH and the global SDG target of 12/1000 KH by 2030. (5)

The Indonesian Health Profile Data for 2023 stated that East Java ranks third in the highest number of neonatal mortality cases, with 3,390 cases. (6) Jember Regency ranks second among regencies in East Java province, with the highest neonatal mortality rate, at 274 cases or 8.2/1000 live births. (6) Data from the Jember Regency Health Office shows that the highest cause of infant mortality is due to neonatal complications, with an estimated neonatal complications in 2023 of 15% or 4,598 of 31,942 live births (7). Previous studies have identified various determinants of neonatal mortality, including maternal characteristics, birth-related factors, and access to healthcare. Maternal characteristics consist of age at delivery, gestational age, mid-upper arm circumference, anemia status, parity, presence of complications, and exposure to cigarette smoke. Infant characteristics include gender, birth order, birth spacing, and birth weight. Meanwhile, utilizing health services includes antenatal care, a birth attendant, the place of delivery, and the method of delivery. (8) A widely cited analysis by Paudel et al. using Demographic and Health Survey (DHS) data shows that neonatal mortality is influenced by household, maternal, infant, and healthcare factors, including maternal age, birth spacing, antenatal care utilization, and environmental exposures. (9) These findings provide important macro-level insights into the epidemiology of neonatal mortality and highlight the role of sociodemographic factors and healthcare utilization. However, the DHS-based analysis relies primarily on nationally collected survey data and self-reported measures, which may limit contextual and clinical specificity.

Based on the study, significant gaps remain in analyzing neonatal mortality rates within the context of local health systems. Subnational variation is particularly relevant in decentralized health systems, where differences in service accessibility, quality of care, and maternal risk profiles can vary significantly across regions. (10) Furthermore, research in Southeast Asia using maternal cohort data or medical

records to explore real determinants of neonatal mortality, particularly at the district level, remains limited. In Indonesia, neonatal mortality rates significantly impact infant mortality rates, but evidence at the district level remains limited. (11,12) Jember Regency is a high-priority area due to persistent high neonatal mortality rates over the past few years, despite ongoing maternal and child health programs. The availability of maternal cohort data and health facility medical records provides a unique opportunity to generate more context-specific and clinically grounded evidence. Therefore, this study aims to examine risk factors for neonatal mortality in Jember Regency using maternal cohort data and medical records. By providing district-level epidemiological evidence in Jember, this study provides new insights beyond national aggregate survey analyses and supports more targeted local interventions to accelerate neonatal survival.

MATERIALS AND METHODS

A quantitative, observational, case-control study was conducted in Jember Regency from January to April 2025. The case population comprised infants aged 0-28 days in Jember Regency, recorded in the neonatal death report from January 2024 to December 2024, totaling 198 cases. The control population consisted of babies who survived to 28 days or more in Jember Regency from January 2024 to December 2024, totaling 23.836 babies. The sample size in this study was calculated using the Lemeshow formula for observational case-control studies.

$$n = \frac{\{Z_{1-\frac{\alpha}{2}}\sqrt{2P_2(1-P_2)} + Z_{1-\beta}\sqrt{P_1(1-P_1) + P_2(1-P_2)}\}^2}{(P_1 - P_2)^2}$$

Based on the sample calculation formula, n is the minimum sample size of the case group and the control group, $Z_{1-\alpha/2}$ is the standard deviation value α = 1.96 (Z_α value at 95% CI, α = 0.05), $Z_{1-\beta}$ is the standard deviation value β = 0.84 (Z_β at 80% power), P_1 is the proportion of the case group exposed to risk factors (P_1 = 0.802), P_2 is the proportion of the control group exposed to risk factors (P_2 = 0.492) based on previous research, OR is the Odds Ratio value based on previous research (OR = 4.2). (13) Based on the sample calculation results, the minimum sample size for each group was 38 respondents. However, to avoid sample dropout, the following sample correction calculation was performed. Therefore, the minimum sample size for each group was 42 respondents.

The sample for this study employed a 1:1 ratio. Therefore, the sample sizes for the case and control groups were 42 respondents each, for a total of 84. This study employed two sampling techniques. The first stage used purposive sampling, selecting five sub-districts and six community health centers (Puskesmas) with the highest neonatal mortality rates in Jember regency in 2024, which were 1)

Sumberjambe community health centers, 2) Silo 1 community health centers, 3) Silo 2 community health centers, 4) Puger community health centers, 5) Bangsalsari community health centers, and 6) Sumberbaru community health centers. The second stage involved randomly selecting samples from the simple random sample, yielding 42 respondents per case and control group.

The independent variables used in this study included maternal characteristics (maternal age, gestational age, parity, mid-upper arm circumference (MUAC), anemia status, complications, and exposure to cigarette smoke), infant characteristics (birth spacing and birth weight), and utilization of health services (antenatal care visits, type of birth attendant, place of birth, type of delivery). Maternal age was dichotomized into at risk (<20 years and >35 years) and not at risk (20-35 years), gestational age was dichotomized into at risk (<37 weeks and >42 weeks) and not at risk (37-42 weeks), parity was number of respondent's pregnancies that resulted in a live birth was dichotomized into not ideal (<2 and >4) and ideal (2-4), MUAC size was dichotomized into at risk chronic energy deficiency (<23.5 cm) and no risk chronic energy deficiency (≥23.5 cm). Maternal anemia status was dichotomized into yes (if hemoglobin levels <11g/dL) and no (if hemoglobin levels ≥11g/dL). Complications mean health problems in the mother and infant from pregnancy to delivery, including pregnancy

complications and childbirth complications (mother: preeclampsia, cardiovascular disease, infection; infant: asphyxia, low birth weight, respiratory failure). Complications were dichotomized into yes (if there are complications) and no (there isn't any complication). Exposure to cigarette smoke means the mother's condition during pregnancy, whether or not she inhales chemicals from cigarette smoke, and was dichotomized into severely exposed (if score 16-32) and slightly exposed (if score 0-15) (14).

Birth spacing was dichotomized into not ideal (< 24 and >60 months) and ideal (24-60 months), birth weight was dichotomized into at risk (< 2500 gr and >4000 gr) and no risk (2500-4000 gr). The number of antenatal care (ANC) visits refers to the mean number of health check-ups received by pregnant women during pregnancy. The number of ANC was dichotomized into appropriate (if the number of ANC is appropriate in each trimester, with a minimum of 6 visits included 1 visit in 1st trimester, 2 visits in 2nd trimester, 3 visits in 3rd trimester) and not appropriate (if the number of ANC is inappropriate in each trimester), as was the place of birth was dichotomized into facility-based and non-facility based, the type of birth attendant was dichotomized into health workers and non-health workers, and the method of delivery was dichotomized into spontaneous (vaginal) and section caesarea (abdominal). (15) The dependent variable was neonatal

mortality, defined as deaths among infants aged 0-28 days after delivery, and was dichotomized into yes (case group) and no (control group).

This research used two primary and secondary data sources. The primary data instrument, adopted from the Secondhand Smoke Exposure Scale (SHSES) developed by Vardavas et al. (2017), measures the level of cigarette smoke exposure experienced by pregnant women. (14) Secondary data were taken from neonatal mortality reports, cohort records, and Maternal and Child Health books. The instrument, a Secondhand Smoke Exposure Scale (SHSES) questionnaire, was tested in the Kalisat and Kaliwates sub-districts, which are the two areas with the highest neonatal mortality rates, following the five sample areas. The Cronbach's Alpha value (0.671>0.6) indicates that the instrument's questions are reliable and can be used for research. Potential confounding was addressed at the study design stage through restriction.

To minimize major clinical heterogeneity, this study included only singleton live births with complete maternal and neonatal cohort records. This restriction was applied to reduce the influence of strong clinical confounders such as multiple gestations and incomplete medical information. The data were analyzed by the chi-square test at a 95% confidence level. The research was conducted and received ethical approval from the Health Research Ethics Commission of the Faculty of Dentistry, University of Jember, under No. 2943/UN25.8/KEPK/DL/2025.

RESULTS AND DISCUSSION

Table 1 above shows that most mothers were aged 20–35 years, had normal MUAC, and were non-anemic, had ideal parity, and were heavily exposed to cigarette smoke during pregnancy. Most mothers in both cases and controls were in the non-risk maternal ages. This study, in line with previous study, shows that the most neonatal deaths occurred in non-risk maternal ages. (16,17) However, other studies showed the neonatal deaths experienced by babies of mothers at a high risk age because the reproductive organs are not optimal for reproduction, and a decline in the function of the uterine organs and immunity, along with the continuous increase in age. (18) The term gestational age can improve maternal and infant outcomes and reduce the risk of neonatal death. (19) Preterm delivery often triggers pregnancy and labor complications, inhibits the baby's growth and development, thus depriving the baby of the energy it should receive, leading to pregnancy and labor complications. This research is also consistent with other studies, which showed that most neonatal deaths occur in mothers who delivered at non-risk gestational age. (20) However, this result is inconsistent with another study, which showed that the majority of neonatal deaths occurred at

Table 1. Distribution of maternal characteristics

Mother's Characteristics	Case		Control	
	n	%	n	%
Maternal Age at Birth				
< 20 & > 35 Years (at risk)	13	31	6	14.2
20-35 Years (no risk)	29	69	36	85.8
Gestational Age at Delivery				
< 37 & > 42 Weeks (at risk)	19	45.2	8	19
37 - 42 Weeks (no risk)	23	54.8	34	81
Mid upper arm circumference (MUAC)				
< 23.5 cm (at risk risk chronic energy deficiency)	5	11.9	7	16.7
≥ 23.5 cm (no risk chronic energy deficiency)	37	88.1	35	83.3
Maternal Anemia Status				
Yes	9	21.4	4	9.5
No	33	78.6	38	90.5
Parity				
< 2 & > 4 (not ideal)	18	42.9	12	28.6
2 - 4 (ideal)	24	57.1	30	71.4
Complications				
Yes	42	0	8	19
No	0	0	34	81
Exposure to Cigarette Smoke				
Severely Exposed (15-32)	32	76.2	30	71.4
Sligthly Exposed (0-14)	10	23.8	12	28.6

high-risk gestational ages. (21) Chronic energy deficiency (CED) can occur due to insufficient intake of macro- and micronutrients required by the body, as pregnant women need more energy to meet their nutritional needs. (22) Chronic Energy Deficiency (CED) reflects long-term maternal undernutrition and has direct biological implications for fetal growth and neonatal survival. Maternal undernutrition impairs placental vascular development, reduces uteroplacental blood flow, and increases the risk of intrauterine growth restriction, small-for-gestational-age (SGA), and low birth weight. Infants born small or preterm have immature organ systems, poor thermoregulation, limited glycogen stores, and compromised immunity, all of which substantially increase the risk of neonatal death. (22, 24) However, the results of another study by Rahmaniar (2020) show that the majority of babies who experience neonatal death come from mothers at risk of chronic energy deficiency during pregnancy. (25)

Anemia in pregnant women increases the risk of pregnancy complications, specifically low birth weight. Lack of iron and oxygen intake due to anemia can cause pregnancy complications, leading to

neonatal death. (26,27) This is in line with research by Farhan & Dhanny (2021), which showed that neonatal deaths occurred in mothers who did not have anemia, but another study by Rahmaniar (2020) showed that the majority of mothers of babies who experienced neonatal death were at risk of anemia during pregnancy. (25,28) Excessive parity or a continuous number of births results in the progressive shedding of blood vessels in the uterine wall and reduced tissue elasticity due to pregnancy, and if the placenta experiences disorders, it directly disrupts fetal growth in the womb, which can increase the risk of pregnancy complications, maternal and neonatal death. (29, 31) This aligns with other showed that neonatal deaths occur in mothers with non-ideal parity or birth order. (32,33) However, another study shows that neonatal deaths often occur at non-ideal parity intervals. (34,35)

The results showed that all neonatal deaths occurred due to maternal and infant complications. Most complications experienced by infants include asphyxia, low birth weight, and respiratory failure, while most mothers experience complications such as preeclampsia and CED. Neonatal and infant mortality are rarely spontaneous events but rather the end result of a cascade of pathological processes initiated during pregnancy or childbirth.(23,36) Asphyxia is a condition in which an infant cannot breathe spontaneously and regularly at birth. This can occur due to impaired gas exchange or to impaired oxygen transport from the mother to the fetus. Asphyxia can cause the baby to experience a rapid decrease in heart rate, blueness, and paleness, weakening reflexes, and ultimately eliminating them, resulting in neonatal death. (37,38) Complications such as preterm birth, intrapartum hypoxia, and neonatal infections represent proximal determinants of neonatal death.(39) Maternal complications that occur during pregnancy, such as preeclampsia, intrauterine infection, premature rupture of membranes, and antepartum hemorrhage, cause impaired uteroplacental perfusion, thereby increasing the risk of fetal distress and premature birth. Intrapartum and postpartum complications are also a significant cause of 24% of neonatal deaths. (28,35,40,42) Intrapartum complications such as prolonged labor, fetal distress, placental abruption, and umbilical cord prolapse cause the baby to experience impaired oxygen flow during delivery, acute hypoxia, metabolic acidosis, brain damage (hypoxic ischemic encephalopathy), multi-organ failure, and ultimately result in neonatal death. (16,34,43) Exposure to cigarette smoke, mainly due to population density and poor ventilation, impacts health during pregnancy. (44,46) Pregnant women who are passive smokers are also at high risk of being exposed to high levels of cigarette smoke.(8,13,47) This is in line with other research that mothers who are

Table 2. Distribution of infant characteristics

Baby Characteristics	Case		Control	
	n	%	n	%
Birth Spacing				
< 24 & > 60 months (not ideal)	20	47.6	26	61.9
24-60 months (ideal)	22	52.4	16	38.1
Baby Birth Weight				
< 2500 & > 4000 g (at risk)	28	66.7	13	31
2,500 – 4,000 g (no risk)	14	33.3	29	69

exposed to cigarette smoke with high intensity (>30 minutes/day, exposed every day, >10 cigarettes/day) are at higher risk of complications that can endanger maternal and neonatal outcomes. (48)

Based on **Table 2** above, ideal spacing was slightly more common among cases. This is consistent with research by Batubara & Fitriani (2021) Most neonatal deaths occur in babies with ideal birth intervals. (37) Birth spacing allows the uterus to recover properly after pregnancy. Uterine elasticity begins to decline due to increasing maternal age, specifically if the space is more than five years, which increases the risk of fetal growth, prolonged labor, or hemorrhage. (9,49,50) Most cases had a risky baby birth weight, which is a contributing factor to neonatal death. Risky birth weight babies experience growth and development disorders, which often trigger complications and even death. Another research shows that low birth weight babies had a higher risk of neonatal death. (11,27,28,33)

Table 3. Distribution of health service utilization

Utilization of Health Services	Case		Control	
	n	%	n	%
ANC Visit				
Inappropriate visit for each trimester	23	54.8	14	33.3
Appropriate visit to each trimester	19	45.2	28	66.7
Birth Attendant				
Non-Healthcare Workers	2	4.8	0	0
Health workers	40	95.2	42	100
Maternity Place				
Non-Healthcare Facilities	2	4.8	0	0
Health Service Facilities	40	95.2	42	100
Delivery Methods				
Vaginal	19	45.2	34	81
Abdominal	23	54.8	8	19

Based on **Table 3** above, in most cases, an inappropriate ANC visit was revealed, with delivery occurring at health services and assisted by health workers, using the abdominal delivery method. ANC visits are a vital health service for pregnant women and fetal growth, providing both physical and mental support, and detecting any disorders or abnormalities during their pregnancy as early as possible. (8,12,23,47) In line with another study, other babies who experienced neonatal death had a history of inappropriate or incomplete ANC visits as recommended. (38,51) However, the results of this study do not align with other research, mothers who made appropriate ANC visits in each trimester experienced neonatal death. (52,53)

Based on **Table 4**, babies born at risky gestational ages have a 3.5 times higher risk of experiencing neonatal death, and mothers who experience complications have a 4.2 times higher risk of experiencing neonatal death. When an infant is born prematurely, the infant's vital organs are not yet mature, so there is a high possibility of respiratory distress syndrome, immune immaturity that makes the newborn

Table 4. Bivariate analysis between maternal characteristics and neonatal mortality

Mother's Characteristics	Case		Control		p-value	OR	95% CI
	n	%	n	%			
Maternal Age at Birth							
< 20 & > 35 Years (at risk)	13	31	6	14.2	0.12	2.69	0.91-7.59
20-35 Years (not at risk)	29	69	36	85.8		1	1
Gestational Age at Delivery							
<37 & >42 Weeks (at risk)	19	45.2	8	19	0.02*	3.511	1.32-9.36
37-42 Weeks (no risk)	23	54.8	34	81		1	1
MUAC							
< 23.5 cm (less)	5	11.9	7	16.7	0.75	0.676	0.19-2.33
≥ 23.5 cm (standard)	37	88.1	35	83.3		1	1
Maternal Anemia Status							
Yes (<11g/dl)	9	21.4	4	9.5	0.23	2.591	0.73-9.19
No (≥11g/dl)	33	78.6	38	90.5		1	1
Parity							
< 2 & > 4 (not ideal)	18	42.9	12	28.6	0.25	1.875	0.76-4.64
2 – 4 (ideal)	24	57.1	30	71.4		1	1
Complications							
Yes	42	0	8	19	< 0.001*	4.2	2.44-7.21
No	0	0	34	81		1	1
Exposure to Cigarette Smoke							
Severely Exposed (15-32)	32	76.2	30	71.4	0.80	1.28	0.48-3.39
Slightly Exposure (0-14)	10	23.8	12	28.6		1	1

*Significance

susceptible to infection, hypothermia, and increased intravascular fragility, thus increasing the risk of intraventricular hemorrhage. (28,43,54) This finding is inconsistent with the other study gestational age and neonatal mortality are not related. (12) However, aligned with the study by Purwanto (2022), the risk of neonatal death is 3.571 times higher in risky gestational age delivery. (20) A premature baby has organ disorders that decrease the capability to survive outside the womb, is susceptible to illness, has a weakened immune system, and is at a higher risk of neonatal death. Meanwhile, postmature babies can be a risk factor for neonatal death due to the aging of the placenta, which affects the distribution of food and oxygen for the fetus during pregnancy. (8,55)

Most complications experienced by babies include asphyxia and low birth weight, while most mothers experience complications of preeclampsia and CED. Asphyxia results in the baby being unable to breathe spontaneously and regularly at birth, so that asphyxia can cause the baby to experience a rapid decrease in heart rate, the body turns blue, and become pale, causing reflexes to weaken or disappear. (48,56) Meanwhile, the results of other studies show that the majority of neonatal deaths occur in mothers who experience CED complications due to low levels of consumption of macro and micronutrients needed by pregnant women, so that the fetus does not get enough nutrition from the

mother, which can affect the outcome of the fetus. (9,26,36) Maternal chronic energy deficiency (CED), proxied by low mid-upper arm circumference (MUAC), contributes to adverse neonatal outcomes through multiple biological pathways. CED compromises maternal protein-energy reserves, reduces placental growth, impairs uteroplacental blood flow, and limits micronutrient transfer to the fetus. This leads to fetal growth restriction and diminished neonatal physiological reserves. A study showed that maternal undernutrition significantly increases the risk of LBW and neonatal mortality in low- and middle-income countries. Furthermore, maternal anemia often coexisting with CED exacerbates placental hypoxia by reducing oxygen-carrying capacity, thereby amplifying fetal vulnerability. (33,34)

Based on **Table 5**, it can be seen that babies born with a high-risk birth weight have a 4.4 times higher risk of experiencing neonatal death. Low birth weight is a contributing factor to neonatal death, including poor or insufficient health care for pregnant women, both during pregnancy and childbirth. Birth weight, identified as a significant factor in this study (OR = 4.462; 95% CI = 1.785-11.154), represents both a biological endpoint and a mediator of maternal risk factors. Low birth weight (LBW) reflects intrauterine growth restriction, prematurity, or both. Recent epidemiological evidence indicates that LBW is strongly associated with neonatal

Table 5. Bivariate analysis between infant characteristics and neonatal mortality

Baby Characteristics	Case		Control		p-value	OR	95% CI
	n	%	n	%			
Birth Spacing							
24-60 months (ideal)	22	52.4	16	38.1	0.27	0.56	0.23-1.33
<24 & >60 months (not ideal)	20	47.6	26	61.9		1	1
Baby Birth Weight							
<2500 & >4000 g (at risk)	28	66.7	13	31	0.002*	4.46	1.78-11.15
2,500 - 4,000 g (no risk)	14	33.3	29	69		1	1

*Significance

death due to impaired metabolic adaptation, hypoglycemia, reduced brown adipose tissue for thermogenesis, and increased infection susceptibility. Importantly, LBW may mediate the relationship between maternal nutritional status and neonatal mortality. (38,54,56,57)

Infants with abnormal birth weight are more likely to undergo emergency cesarean section secondary to obstetric complications, which themselves increase the risk of neonatal mortality, which is often performed due to underlying obstetric complications. (36,58) Delivery mode may intersect with this pathway at the level of obstetric complication management. High-risk fetuses with intrauterine growth restriction or distress are more likely to undergo emergency cesarean section. (59) Consequently, abdominal delivery may represent the culmination of severe antecedent pathology rather than an independent etiological factor. Recent studies have shown that cesarean delivery performed under emergency conditions is associated with increased adverse neonatal outcomes, particularly in high-risk pregnancies. (59) Therefore, delivery mode may act as a confounding factor in the relationship between birth weight and neonatal mortality, as it reflects pre-existing clinical complications rather than serving as an independent causal factor. Low birth weight babies are more likely to die, especially during the neonatal period, because babies born with low birth weight experience growth and development problems, which are more likely to trigger complications and even death. (26,27) Another research shows that babies who experience neonatal death are included in the category of babies with high-risk birth weight. Some problems that often arise in low birth weight babies include unstable body temperature, respiratory disorders, digestive disorders, disturbances in the growth and development process and maturation of organs and other body parts, which are more likely to trigger complications and even death. (42)

Based on **Table 6** he present study identified gestational age at delivery,

Table 6. Bivariate analysis between utilization of health services and neonatal mortality

Utilization of Health Services	Case		Control		p-value	OR	95% CI
	n	%	n	%			
ANC Visit							
Inappropriate visit for each trimester	23	54.8	14	33.3	0.08	2.42	1.00-5.86
Appropriate visit for each trimester	19	45.2	28	66.7		1	1
Birth Attendant							
Non-Healthcare Workers	2	4.8	0	0	0.47	2.05	1.64-2.56
Health workers	40	95.2	42	100		1	1
Maternity Place							
Non-healthcare	2	4.8	0	0	0.47	2.05	1.64-2.56
Health Facilities	40	95.2	42	100		1	1
Delivery Methods							
Vaginal	19	45.2	34	81	0.002*	0.194	0.07-0.52
Abdominal	23	54.8	8	19		1	1

*Significance

obstetric complications, birth weight, and delivery method as significant determinants of neonatal mortality in Jember Regency. Pregnant women who are aware of the risks of delivering with unskilled aid and services that do not meet standards tend to choose qualified and guaranteed healthcare facilities such as hospitals, community health centers, and independent midwife practices to ensure the safety of the mother and baby. (23,32,58) While infants delivered via abdominal methods and those born in healthcare facilities were more frequently represented in the mortality group, this pattern should not be interpreted as evidence that institutional or operative delivery intrinsically increases neonatal mortality. (24,59) Rather, this association most plausibly reflects the clinical severity of high-risk pregnancies that require referral and surgical intervention. Recent global analyses have emphasized that cesarean section is frequently performed in response to severe obstetric conditions, including fetal distress, preeclampsia, antepartum hemorrhage, obstructed labor, and extreme prematurity. A comprehensive review demonstrated that adverse neonatal outcomes associated with cesarean section are largely attributable to the underlying maternal–fetal complications prompting the procedure rather than the surgical intervention itself. (58) Similarly, another study reported that the relationship between cesarean delivery rates and neonatal mortality is highly context-dependent and strongly influenced by indication bias. (59) Therefore, the observed association in our study likely reflects confounding by indication, in which operative delivery serves as a marker of severe pathology rather than a causal determinant.

Biologically, several interconnected mechanisms explain the elevated mortality risk observed in neonates exposed to high-risk maternal conditions. First, obstetric complications frequently lead to impaired uteroplacental perfusion and fetal hypoxia. Prolonged hypoxic exposure results in metabolic acidosis, hypoxic–ischemic encephalopathy, and multi-organ dysfunction, which are major contributors to early neonatal death. Second, many complicated pregnancies culminate in preterm delivery. (49,60,61) Prematurity is characterized by pulmonary immaturity with surfactant deficiency, fragile cerebral vasculature predisposing to intraventricular hemorrhage, impaired immune function, and limited thermoregulation capacity. These biological vulnerabilities substantially increase susceptibility to respiratory distress syndrome, sepsis, and mortality. (28,62) Studies confirmed that prematurity and low birth weight remain the strongest proximal predictors of neonatal mortality globally. (8,33,43)

This is consistent with other research showing that mothers of infants who experience neonatal death receive assistance from healthcare professionals during delivery. (18,63,64) Furthermore, this is consistent with Prambudi's (2021) research shows that mothers of infants who experience neonatal death have a history of delivering at healthcare facilities such as hospitals, community health centers, and independent midwife practices. (65)

Abdominal delivery is a condition of delivery that has been previously planned due to the complications experienced by the pregnant woman. This is according to the research of Putri et al. (2025), which shows that mothers of babies who experience neonatal death have a history of giving birth using the abdominal method. (63) The results of the study stated that 15% of deliveries in developing countries are delivered by the abdominal method, and this has both positive and risky impacts on the mother and fetus (48). Meanwhile, spontaneous labor is a method of giving birth directly through the vagina and is considered the safest method of delivery, and is recommended for mothers with healthy pregnancies.(31,66)

Our findings raise important considerations for the health system. The result of this study showed that neonatal deaths occurred predominantly in healthcare facilities may indicate delayed referral, suboptimal intrapartum monitoring, or gaps in emergency obstetric and neonatal care (EmONC) capacity. Various study indicates that improvements in survival depend not only on increasing institutional delivery rates but also on strengthening the quality of care, ensuring timely decision-to-incision intervals, ensuring neonatal resuscitation readiness, and ensuring postnatal monitoring. (10,16,34) The retrospective case–control design and reliance on bivariate analysis without multivariable adjustment increase

the risk of residual confounding and limit causal inference. The observed association between delivery method and neonatal mortality may be influenced by confounding by indication, selection bias due to referral patterns, and severity clustering in higher-level facilities where complicated cases are concentrated. Future research using multivariable regression models and prospective cohort designs with detailed clinical severity indicators is required to better estimate the independent effects of maternal and delivery-related factors on neonatal mortality.

CONCLUSION AND RECOMMENDATION

This study determined several factors statistically associated with neonatal mortality in Jember Regency, including preterm and post-term birth, maternal complications, abnormal birth weight, and abdominal delivery. These findings suggest that neonatal mortality is closely related to maternal clinical conditions, fetal growth status, and delivery characteristics. Strengthening early detection and management of high-risk pregnancies should be prioritized within antenatal care (ANC) services in Jember Regency. The District Health Office may consider enhancing routine screening for gestational age risk, maternal complications, nutritional status (including CED and anemia), and fetal growth monitoring at primary healthcare facilities. Improving referral coordination and response time between primary care centers and hospitals, particularly for obstetric emergencies, is also recommended to reduce delays in care. Additionally, capacity-building for healthcare workers and Posyandu cadres in risk identification and documentation may improve early recognition of complications. Finally, future research using multivariable analytical models and more clinical indicators is recommended to better estimate independent risk factors and guide evidence-based policy development.

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