Journal of Chemical Health Risks

www.jchr.org

JCHR (2026) 16(1), 2516-2523 | ISSN:2251-6727

A Retrospective Cross-Sectional Study on the Determinants of Post-Neonatal Under-Five Mortality (U5M) in Kota Kinabalu, Sabah: Analysis of Under-Five Mortality Data from 2020 to 2024

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(Received: 05 December 2025 Revised: 15 January 2026 Accepted: 10 February 2026)

KEYWORDS

Infant Mortality,

Post neonatal Mortality,

Risk Factors,

Maternal Health,

Socioeconomic Factors,

Malaysia

ABSTRACT:

Introduction: Under-five mortality (U5M) is a key indicator of child health and socio-economic development. Despite global efforts to reduce child deaths, disparities persist, especially in marginalized regions such as Sabah, Malaysia.

Objectives: This study focuses on identifying the determinants of post-neonatal U5M (children aged 1–59 months) in Kota Kinabalu, Sabah.

Methods: A retrospective cross-sectional study was conducted using mortality data from the Kota Kinabalu District Health Office from 2020 to 2024. All eligible post-neonatal death cases were included through total population sampling. Data were extracted using a structured form and analysed using descriptive statistics, chi-square tests, and multivariate logistic regression in R software.

Results: Infants aged 1–11 months accounted for most deaths. Citizenship status was significantly associated with preventable deaths, with non-citizen children having higher odds of preventable mortality compared to Malaysian citizens (adjusted OR: 0.43; 95% CI: 0.24–0.74; p = 0.003). Each additional week of gestation increased the odds of preventable death (adjusted OR: 1.15; 95% CI: 1.06–1.25; p = 0.001). The final logistic regression model demonstrated fair discriminatory power with an AUC of 0.713.

Conclusions: The study showed significant inequalities in post-neonatal U5M among non-citizen populations and emphasizes the need for improved access to healthcare, maternal education, and antenatal care. These findings can inform targeted policies and public health interventions to reduce preventable child mortality and support progress toward Sustainable Development Goal 3.2.

1. Introduction

The Under-five mortality (U5M) remains a vital indicator of a country's health system performance and overall socio-economic development. Globally, substantial improvements have been made in child survival over the past few decades. The global under-five mortality rate declined from 94 deaths per 1,000 live births in 1990 to 37 in 2023, representing a 61% reduction [1]. In 2023, approximately 4.8 million children under the age of five died globally, translating to around 13,100 deaths each day. A significant proportion of these deaths could have been prevented through basic and cost-effective public health measures [2] Sustainable Development Goal (SDG) 3.2 sets a target to reduce global under-five mortality to no more than 25 deaths per 1,000 live births by the year 2030. Achieving this objective necessitates concerted efforts not only at the national level but also at the sub-national level, with a focus on identifying and addressing local factors contributing to child mortality [3].

Malaysia, as a middle-income country, has achieved notable progress in reducing under-five mortality. Since

Journal of Chemical Health Risks
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JCHR (2026) 16(1), 2516-2523 | ISSN:2251-6727

the 1980s, the nation has witnessed a consistent downward trend in child mortality, from 30.0 per 1,000 live births in 1980 to 8.0 per 1,000 by 2004 [4]. This progress is largely attributed to improved maternal and child health services, higher rates of immunization, and better access to clean water and sanitation [5]. However, this national average masks disparities among different regions and population groups. States in East Malaysia, particularly Sabah and Sarawak, consistently report higher child mortality rates, reflecting inequalities in healthcare access, socio-economic status, and environmental conditions [6].

Sabah, located on the island of Borneo, presents a unique and complex context for understanding under-five mortality. As the second-largest state in Malaysia, Sabah is home to a diverse population, including many indigenous communities, stateless individuals, and migrants. These groups often face significant barriers to accessing healthcare due to geographical isolation, language differences, and legal status. According to the Department of Statistics Malaysia, Sabah has consistently reported higher neonatal and under-five mortality rates compared to the national average [7]

Post-neonatal mortality, defined as deaths among children aged 1 month to 59 months, constitutes a significant proportion of under-five deaths. In 2022, approximately 50% of under-five deaths were attributed to post-neonatal causes [3]. Post-neonatal mortality is frequently associated with preventable causes such as malnutrition, respiratory infections, diarrheal diseases [8], and limited access to timely healthcare [9]. The post-neonatal period is a vulnerable time for child survival, especially in settings where healthcare resources are inadequate, and socio-economic hardships persist.

Maternal health is another critical determinant of child survival. Factors such as antenatal care attendance, maternal age, nutritional status, and birth spacing directly affect child health outcomes. According to a national study in Malaysia, inadequate antenatal care, non-compliance with medical advice, and suboptimal delivery conditions were significantly associated with preventable stillbirths and neonatal deaths [10]. In the context of post-neonatal mortality, maternal behaviour and awareness of child illness symptoms are vital for prompt treatment-seeking and care. These findings underscore the need for targeted research and localized strategies to reduce preventable child deaths in the state.

Access to healthcare services is fundamental in determining child mortality outcomes. Geographic distance, affordability, transportation barriers, and quality of services influence whether families seek and receive adequate healthcare for their children. In rural and hard-to-reach communities, delays in treatment for common childhood illnesses often result in fatal outcomes [11]. In Sabah, which includes both urban and remote areas, such inequalities are more pronounced. For example, children living in households with poor sanitation and lower income had significantly higher risks of acute diarrhoea which is a major cause of post-neonatal deaths in developing settings in Sabah (Madrim et al., 2021).

2. Objectives

This study aims to achieve three main objectives. First, it seeks to describe the demographic and clinical profiles of post-neonatal under-five mortality cases in Kota Kinabalu from 2020 to 2024. This includes examining variables such as age, sex, ethnicity, place of residence, and clinical characteristics like cause of death, comorbidities, and access to healthcare services. Second, the study aims to determine the association between socioeconomic status and maternal health factors with post-neonatal under-five mortality. This will involve assessing indicators such as household income, parental education, employment status, antenatal care attendance, maternal age, parity, and delivery-related complications to identify significant correlates of mortality. Third, the study intends to determine the predictive factors for post-neonatal under-five mortality cases in Kota Kinabalu during the same period.

3. Methods

Study Setting

This study was conducted in Kota Kinabalu, the capital city of Sabah, located in East Malaysia on the island of Borneo. Kota Kinabalu represents a mixed urban-peri urban setting, with a diverse population that includes both Malaysian citizens and non-citizen communities, such as indigenous groups and undocumented migrants. The city is served by several healthcare facilities including public hospitals, health clinics (Klinik Kesihatan), and maternal and child health centres, which will serve as primary sources of mortality data. The study will utilize data from official health records, death registration systems, and public health departments operating under the Ministry of Health Malaysia,

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specifically focusing on cases recorded between 2020 and 2024.

Study Design

This research was adopted a retrospective cross-sectional study design. It involves the collection and analysis of existing mortality data on post-neonatal under-five deaths (children aged 1 month to 59 months) that occurred within the defined study period.

Sampling Method

Purposive sampling was used to all post-neonatal under-five mortality cases (children aged 1 month to 59 months) that meet the inclusion criteria and were recorded in Kota Kinabalu between 1st January 2020 and 31st December 2024.

Sample Size

As this is a retrospective study, the sample size is dependent on the availability of recorded mortality cases that meet the study's inclusion criteria. Based on preliminary estimates from National Registration Department, it is anticipated that the total number of post-neonatal under-five deaths in Kota Kinabalu over the five-year period will range between 300 to 500 cases [7]. All eligible cases within this range will be included, ensuring that the sample reflects the true population of interest. However, the recorded data that fulfil the eligible criteria was 233 cases.

Research Tools

The instrument used in this study is a structured data extraction form in Microsoft Excel that developed specifically for the purpose of systematically collecting relevant information from existing primary sources. These sources include mortality records from the Kota Kinabalu District Health Office. The data extraction form was designed to capture essential variables associated with post-neonatal under-five mortality, ensuring consistency, completeness, and reliability of the data collected. The instrument comprises two main sections:

(i) child-related information, including age at death, sex, ethnicity, cause of death, and place of death

(ii) maternal characteristics such as marital status, maternal age, education level, household income and antenatal care visits

Data Analysis

All data was entered and analysed using R software. Descriptive statistics was used to summarized the characteristics of the study population, including frequencies, percentages, means, and standard deviations for categorical and continuous variables, respectively. For bivariate analysis, the association between independent variables (post-neonatal under-five factors and maternal healthcare) and the outcome variable (post-neonatal under-five mortality) will be tested using the Chi-square test for categorical variables and independent t-tests for continuous variables, as appropriate. Variables found to be significant at $p < 0.25$ in the bivariate analysis was included in the multivariate logistic regression model to identify independent predictors of preventable mortality [13]. Adjusted Odds Ratios (AOR) with 95% Confidence Intervals (CI) was reported to estimate the strength of association. A significance level of $p < 0.05$ will be considered statistically significant in the final model.

Data also examined for multicollinearity, and the goodness-of-fit of the regression model was assessed by the Hosmer-Lemeshow test. Additionally, the optimal cut-off point for the predicted probability was determined using Youden's Index to achieve the best balance between sensitivity and specificity. A confusion matrix and mosaic plot was used to visually assess the agreement between actual and predicted outcomes, providing further insight into the model's predictive accuracy and classification performance.

Research Ethic

This study adhered to strict ethical and data protection standards. All data were stored securely on password-protected computers and encrypted storage devices, accessible only to authorized research team members. Any physical documents used during data extraction were kept in locked cabinets and were destroyed upon study completion. To maintain confidentiality, all datasets were anonymized, with personal identifiers removed prior to analysis.

Ethical approval was granted by the Medical Research and Ethics Committee (MREC), Ministry of Health Malaysia (Approval No: NMRR-24-234-81239). As the study utilized anonymized secondary data, informed consent was not applicable. As a retrospective study using secondary data, there was no direct contact with participants.

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4. Results

Demographic and clinical profiles of post- neonatal under-five mortality cases in Kota Kinabalu from 2020 to 2024.

Based on the sociodemographic distribution of post-neonatal deaths, Table 1 showed higher post neonatal deaths occurred among infants aged one to eleven months. The distribution of citizenship status is nearly equal between Malaysian and non-Malaysian children. Regarding the death category, most cases were classified as preventable death. Higher number of the mothers were within the prime reproductive age of twenty to thirty-four years. Regarding marital status, the data showed that most mothers were married. In terms of educational attainment, a concerning finding is that a significant number of mothers had no formal education. Household income data shows that most families were living with very limited financial resources of less than RM 1000 per month. Finally, the status of antenatal care (ANC) visits shows that mostly mothers had completed ANC visits.

Table 1: Sociodemographic distribution of post neonatal and maternal factor

Sociodemographic factor	Frequency (n=233)	Percentage (%)
Post-neonatal factor		
Age category		
Infant (1–11 months)	113	38.50
Toddler (12–23 months)	43	18.45
Preschool-aged (24–59 months)	77	33.05
Citizenship Status		
Malaysian	116	49.79
Non-Malaysian	117	50.21
Death Category		
Preventable	138	59.23
Not preventable	95	40.77
Maternal factor		
Mother's age	11	4.72
Adolescent (<20 years)		
Prime reproductive age (20–34 years)	168	71.67
Advanced maternal age (>35 years)	57	23.61
Marital Status	211	90.56
Married		
Unmarried	20	8.56
Divorced	2	0.86
Educational Level	130	55.79
No formal education		
Primary education	33	14.16
Secondary education	51	21.89
Tertiary education	19	8.15
Household Income	202	86.70
RM 0–3000		
RM 3001–7000	26	11.16
>RM 7000	5	2.15
Antenatal Care Visit	115	49.36
Complete		
Incomplete	78	33.48
Not Clinical Case	40	17.17

Association between socioeconomic status and maternal health factor with post-neonatal under-five mortality

A Chi-square test was conducted to determine the association between citizenship status, and the preventability of under-five deaths showed a statistically significant relationship ($\chi^2 = 10.588$, df = 1, p = 0.0011). Among non-citizens had more preventable deaths than non-preventable ones while citizens had a relatively balanced distribution between preventable and non-preventable deaths. Then, a t-test was conducted to compare mean gestational age at birth between preventable and non-preventable post neonatal under-five deaths. The results showed a statistically significant difference (t = -3.56, df = 145.38, p = 0.0005). The non-preventable deaths were associated with a lower mean gestational age of 35.43 weeks, whereas preventable deaths occurred at a higher mean gestational age of 37.57 weeks.

A one-way ANOVA was conducted to test whether the mean post- neonatal age at death differed significantly across maternal age categories. The results showed a statistically significant difference (F (2, 230) = 3.555, p = 0.0302). Then, Tukey's post-hoc test was performed. The only significant difference detected was between prime reproductive age (20–34 years) and advanced maternal age (>35 years) (p = 0.03). This indicates that advanced maternal age is associated with significantly different (and likely poorer) outcomes compared to prime reproductive age.

The predictive factor for post-neonatal under-five mortality

In the simple logistic regression analyses, each independent variable was tested separately to examine its unadjusted association with the odds of experiencing a preventable post-neonatal death as in Table 2. Household income did not show a significant relationship in both low- and middle-income categories had negative coefficients, indicating a potential protective trend compared to high-income households, but these

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associations were not statistically significant ($p > 0.20$). For maternal education, having secondary education was significantly associated with lower odds of preventable death compared to mothers with no formal education ($p < 0.01$), while primary and tertiary education levels did not demonstrate significant effects.

Marital status categories did not show any significant association with preventable deaths in this unadjusted model. Citizenship status, however, showed a strong relationship which is Malaysian mothers had significantly lower odds of experiencing preventable post-neonatal death ($p < 0.01$), whereas non-Malaysian status was associated with higher odds ($p < 0.01$).

Mother's age per year increase was not statistically significant ($p = 0.80$). Regarding antenatal care, incomplete ANC status was significantly linked to higher odds of preventable death ($p = 0.03$), while non-clinic cases were not significant. Child age categories (toddler and preschool-aged) did not show significant differences compared to infants. Finally, each additional week of gestational age was significantly associated with increased odds of preventable post-neonatal death ($p < 0.01$).

Table 2: Simple logistic regression for the predictors with the preventable death of post neonatal under five

Variable	Coefficient (β)	Standard Error	Z-value	P-value
Income				
Low income	-0.99	1.13	-0.88	0.38
Middle income	-1.39	1.19	-1.17	0.24
High income	1.39	1.12	1.24	0.22
Education				
No formal education	0.71	0.19	3.78	<0.01
Primary education	-0.27	0.40	-0.68	0.50
Secondary education	-1.06	0.34	-3.12	<0.01
Tertiary education	-0.60	0.50	-1.21	0.23
Marital Status				
Married	0.00	0.00	0.24	0.81
Unmarried	0.00	0.00	0.57	0.57
Divorce	0.00	0.00	0.00	0.00
Citizenship				
Malaysian	-0.92	0.27	3.35	<0.01
Non-Malaysian	0.85	0.20	4.22	<0.01
Mother Age (per year)	-0.01	0.02	-0.25	0.80
ANC status				
Non clinic case	0.42	0.38	1.13	0.26
Incomplete	0.66	0.31	2.17	0.03
Complete	0.09	0.19	0.47	0.64
Child age				
Infant (1-11 months)	0.16	0.19	0.85	0.40
Toddler (12-23 months)	0.57	0.38	1.51	0.13
Pre-school (24-59 months)	0.34	0.30	1.14	0.25
Gestational age (per week)	0.15	0.04	3.55	<0.01

Final model of multiple logistic regression for the predictors with the preventable death of post-neonatal under five

In the final multiple logistic regression model determining factors associated with preventable post-neonatal mortality, all variables with p value< 0.25 were selected to put in the model (13). Two variables remained statistically significant which are gestational age and citizenship status as in Table 4. The finding showed that for each additional week of gestation, the odds of experiencing a preventable death increased by approximately 15% (adjusted odds ratio [OR]: 1.15; 95% confidence interval [CI]: 1.06 to 1.25; p = <0.01).

Then, citizenship status showed a protective effect which is children with Malaysian citizenship had significantly lower odds of preventable mortality compared to non-citizens (adjusted OR: 0.43; 95% CI: 0.24 to 0.74; p = <0.01). This indicates that being a citizen reduced the likelihood of preventable death by approximately 57%, highlighting potential disparities in access to healthcare services and social protection mechanisms for non-citizen families.

The final logistic regression model demonstrated fair discrimination, with an AUC of 0.713, and good

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calibration confirmed by the Hosmer-Lemeshow test ($p > 0.05$). Sensitivity and specificity were 55.1% and 76.8% respectively at a cut-off probability of 0.695. The model explained 18% of the variance (Nagelkerke $R^2 = 0.18$) and showed low multicollinearity (VIF < 1.2 for all predictors).

5. Discussion

This study identified citizenship status and gestational age as significant predictors of preventable post-neonatal under-five mortality in Kota Kinabalu from 2020 to 2024. Specifically, non-citizen children had significantly higher odds of experiencing preventable deaths compared to Malaysian citizens. Moreover, each additional week of gestation was associated with an increased likelihood of preventable mortality.

Socioeconomic Disparities

Barriers such as lack of documentation, legal restrictions, and affordability of healthcare services contribute to reduced utilization of preventive and curative services among stateless and undocumented communities in East Malaysia [14]. This impacting the ability to receive timely and adequate medical care during critical stages such as the post-neonatal period-seeking, increase exposure to preventable conditions, and worsen outcomes [15].Undocumented migrants face uniform non-citizen fees in public hospitals, which can be prohibitive [16].

Additionally, both documented and undocumented migrants encounter barriers such as financial limitations and fear of deportation, exacerbating their healthcare access challenges [17, 18]. Recommendations for addressing these disparities include improving access to healthcare services and implementing targeted interventions to reduce preventable deaths among all children, regardless of citizenship status (Ahmad, Norain Rozita, Ab Rahman Rosnah, 2023).

Gestational Age and Mortality Risk

The finding that longer gestational age increases the odds of preventable post-neonatal mortality aligns with the "gestational age paradox." This paradox suggests that while preterm infants face immediate risks, those who survive may still be vulnerable to external factors like infections and injuries later. This survivor bias shifts attention from biological vulnerabilities at birth to preventable causes during infancy, such as inadequate healthcare access or environmental hazards [20]

Maternal Education and ANC Utilisation

Although not retained in the final multivariable model, simple logistic regression revealed that mothers with secondary education had significantly lower odds of experiencing a preventable post-neonatal death compared to mothers with no formal education. This reinforces evidence that maternal literacy is critical for child survival, influencing awareness of hygiene, feeding practices, and healthcare utilization [21]. Additionally, incomplete antenatal care (ANC) was associated with higher odds of preventable mortality in unadjusted analyses, underscoring the importance of ensuring pregnant women receive complete ANC visits as recommended by the Ministry of Health Malaysia [22]

Recommendation

These findings reinforce the urgent need to address inequities faced by non-citizen families in Sabah. Universal access to child healthcare services, regardless of citizenship status, is crucial in reducing preventable deaths among non-citizen families in Sabah. Community-based outreach and culturally sensitive health education may further bridge gaps for vulnerable populations [23].

Maternal education and complete antenatal care are essential for early detection and management of risk factors, thereby reducing infant mortality [24]. Strengthening community health worker programs and ensuring compliance with antenatal care guidelines are critical steps in enhancing healthcare outcomes for non-citizen families in Sabah [25]. Effective policies that promote equitable healthcare utilization in rural areas of Sabah are necessary for guiding comprehensive healthcare reforms [23].

Strengths and Limitation

A notable strength of this study is the use of total population sampling and comprehensive multivariate analysis. The study's reliance on standardised ICD-10 coding enhances replicability. However, limitations include the use of secondary data, which may contain missing or misclassified variables. Important risk factors such as household environment, nutrition, and immunisation status were not available, limiting the scope of the analysis. Additionally, retrospective data collection limits causal inference.

The period between 2020 and 2021 overlapped with the COVID-19 pandemic, which likely disrupted healthcare services, including antenatal and pediatric care.

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Movement restrictions, fear of exposure, and reallocation of healthcare resources may have affected health-seeking behavior and service accessibility, possibly influencing the distribution and nature of recorded mortality during this time. These factors should be considered when generalizing the findings.

Policy Implication

The findings of this study have important implications for public health policy and the actions of various healthcare stakeholders. At the national level, the Ministry of Health (MOH) should consider revising existing policies to ensure that all children, regardless of their citizenship or legal status, are entitled to essential healthcare services. This inclusive approach would help reduce disparities in access to care and support the overarching goal of universal health coverage.

At the service delivery level, primary health care can play a proactive role by implementing targeted outreach programme, providing mobile clinics, and conducting culturally appropriate health education sessions specifically designed for high-risk non-citizen communities. Such efforts would help bridge the gap in service utilization and improve health outcomes among marginalized populations. Furthermore, community health workers should be mobilized to focus on maternal education, conduct regular home visits, and facilitate the early identification and referral of illness among children in under-served areas. Collectively, these stakeholder-driven strategies can contribute significantly to reducing preventable child mortality and promoting health equity across all segments of the population.

Conclusion

In summary, this study highlights that citizenship status and gestational age are significant predictors of preventable post-neonatal under-five mortality in Kota Kinabalu. While the model shows fair discrimination, additional predictors such as child immunization, nutrition status, breastfeeding practices, postnatal home environment, and care-seeking behavior may improve predictive performance. Targeted interventions focusing on equitable healthcare access and maternal education are recommended to mitigate preventable child deaths and achieve sustainable development goals for child survival.

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