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Title: From Birth Size to Birth Order: Predictors of Child Mortality

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Abstract

Background: Child mortality is a significant public health issue in Indonesia, influenced by various factors. Understanding key predictors is crucial for effective interventions. This study analyses predictors of child mortality using secondary data from the 2017 Indonesia Demographic Health Survey (IDHS) and evaluates the predictive ability of birth size and birth order through Receiver Operating Characteristic (ROC) analysis.

Method: It was a cross-sectional study using secondary data from 2017 IDHS. A total of 13,946 respondents were recruited by multistage stratified random sampling. This study only included one child per mother to clarify the analysis and avoid confusion. Accordingly, the last-born children under five were chosen as the 2017 IDHS collects the most complete and detailed information about the most recent child. The data were analysed using bivariate and multivariate techniques to examine associations between child mortality and factors such as birth size, birth order, maternal education, and socioeconomic status. The ROC curve assessed the model's predictive performance. The data for this study were analysed using Statistical Package for Social Sciences (SPSS) version 21 (IBM, USA). The significance level was set at $P < 0.05$.

Results: Significant predictors included maternal education (p-value: < 0.001 ; OR: 3.750; 95% CI: 1.23-11.34), birth size (p-value: < 0.001 ; OR: 0.130; 95% CI: 0.03-0.44), and birth order (p-value: < 0.001 ; OR: 0.168; 95% CI: 0.09-0.30). Multivariate analysis showed that larger birth sizes were associated with higher mortality odds than very small children (p-value: < 0.005 ; OR: 5,964; 95% CI: 1,698-20,942). First and second-born children had higher mortality risks (p-value: < 0.001 ; OR: 5.209; 95% CI: 2.861-9.483). The ROC analysis revealed modest predictive ability, with area under the curve (AUC) values of 0.611 for birth order and 0.582 for birth size.

Conclusion: Birth size and birth order significantly predict child mortality, but their predictive power is limited. Expanding models to include maternal health and socioeconomic factors is necessary. Public health efforts should enhance prenatal care, particularly for early-born children, and address disparities to improve child survival outcomes.

Keywords: Child Mortality, Birth Order, Birth Weight, Socioeconomic Factors, ROC analysis

Highlights

- **Demographic and Socioeconomic Profile:** The study analyzed data from 13,946 respondents in Indonesia, revealing a balanced demographic distribution in age, sex, and urban-rural residence.
- **Maternal Education and Child Survival:** Children of mothers with no formal education had significantly higher odds of mortality compared to those with higher education.
- **Birth Characteristics:** Birth size emerged as a critical predictor of child mortality, with very large and larger-than-average children showing significantly increased odds of mortality.
- **Birth Order Influence:** First and second-born children exhibited higher odds of mortality compared to those of higher birth orders, indicating potential resource and caregiving disparities. First and second-born children may face higher mortality because their parents are less experienced and may have fewer resources and support compared to later-born children.
- **Model Predictive Ability:** The predictive model, focusing on birth size and order, achieved moderate accuracy, with an AUC of 0.611 for birth order and 0.582 for birth size, suggesting further refinement.

Plain Language Summary

This study explored factors affecting child mortality in Indonesia using data from nearly 14,000 respondents. The results highlight the importance of maternal education, birth characteristics, and family dynamics in child survival. Children born to mothers without education or experiencing complications like vaginal bleeding during pregnancy face higher risks of mortality. Additionally, the size of the child at birth and their birth order significantly influenced survival chances, with extremes in birth size and lower birth orders linked to increased risks.

The study also developed a predictive model to assess these factors' impact on child mortality. However, its accuracy was moderate, suggesting more comprehensive data and additional predictors are needed. These findings emphasize the need for tailored interventions focusing on maternal education, prenatal care, and equitable resource allocation to reduce child mortality in Indonesia.

Introduction

Information on mortality among children under five years is vital for describing a country's health status and the community's quality of life (Debere and Adjiwanou, 2024; Hossain *et al.*, 2024). At the same time, the mortality of children under five years is a crucial measure of a country's socioeconomic and demographic progress and quality of life, particularly in families (Wahl *et al.*, 2023). Lack of competent human resources, poor infrastructure, and underinvestment in health systems have dramatically raised child mortality rates in low- and middle-income countries (Dauda *et al.*, 2024; Mekonnen *et al.*, 2024a).

Child mortality is still a crucial global issue, particularly in Indonesia. The mortality rate for children under five years of age declined by 49%, from 77 deaths per 1000 live births in 2000 to 39 deaths in 2017, or one in every 14 children dying in 2017 (World Health Organization, 2019). Indonesia has attempted to reduce child mortality yearly, and the rate is decreasing. The 2017 Indonesia Demographic and Health Survey (IDHS) statistics show a neonatal mortality rate of 15 per 1,000 live births, an infant mortality rate of 24 per 1,000 live births, and a toddler mortality rate of 32 per 1,000 live births (Ministry of Health Indonesia, 2019; Hanadian Nurhayati-Wolff, 2021). Of course, this statistic remains far from the Sustainable Development Goals (SDGs), which targeted the child mortality rate at 12 per 1,000 live births (World Health Organization, 2015).

In 2019, low birth weight (LBW) (Wulandari *et al.*, 2022) was the leading cause of infant death in Indonesia. Other reasons for death were hypoxia, congenital disabilities, infection, and newborn tetanus (Soleman, 2020). In Indonesia, the factors influencing child mortality include maternal age at birth, birth spacing, and the kid's weight at birth. A child's birth weight affects their nutritional health and immunological system (Soleman, 2020). Indonesia's national policy for children's health states that every kid has the right to survive, grow, and develop, as well as the right to be protected from violence and discrimination, so it is vital to carry out integrated, comprehensive, and sustainable child health initiatives (Kemenkes RI, 2022). Child health efforts in Indonesia include health services for the fetus in the womb, newborn health, infant health, toddlers and preschoolers, health for school-age children and adolescents, and child health protection (Kemenkes RI, 2022). However, Indonesia strives to reduce the mortality rate of children under five by the SDGs target by 2030.

This research introduces a novel approach by employing Receiver Operating Characteristic (ROC) curve analysis to assess and compare the predictive accuracy of various models in identifying key factors contributing to child mortality in Indonesia. Unlike previous studies that have examined the determinants of child mortality, this research distinguishes itself by focusing on the use of ROC curves—a method not commonly applied in public health research within this context. By integrating ROC analysis, the study offers a more robust and comprehensive evaluation of predictive models, highlighting their sensitivity, specificity, and accuracy. Furthermore, the research provides context-specific insights by addressing Indonesia's unique socioeconomic, cultural, and healthcare-related factors, ensuring that the findings are highly relevant to local policymakers and healthcare providers.

Despite extensive global research on child mortality, significant gaps remain, particularly within the Indonesian context. One such gap is the limited application of ROC analysis in public health research on child mortality in Indonesia, which this study addresses by offering a nuanced

understanding of the predictive power of various factors. Additionally, while much of the existing literature relies on generalized models, this research focuses on Indonesia-specific data, providing insights more applicable to the local context. The study also bridges the gap in integrating multiple predictors by evaluating them simultaneously through ROC analysis, allowing for a more comprehensive understanding of their collective impact. Finally, by systematically comparing different predictive models, the research addresses the lack of comparative analysis in existing studies, ultimately identifying the most effective strategies for reducing child mortality in Indonesia.

The theoretical foundation of this study is rooted in the determinants of child mortality, which encompass a range of demographic, socioeconomic, biological, and healthcare-related factors. The conceptual model integrates key elements from public health and epidemiological theories, such as the life course perspective and the social determinants of health framework. These frameworks emphasize the interplay of maternal, neonatal, and environmental factors in shaping child survival outcomes. Maternal education, socioeconomic status, and access to healthcare are critical predictors that influence child health and mortality (Ogunniyi *et al.*, 2024; Zhang *et al.*, 2024). These elements provide a structured approach to understanding the multifaceted nature of child mortality, aligning with global health theories on inequality, access to resources, and health system efficiency.

The conceptual framework of this research introduces ROC analysis as a novel method to evaluate predictive models of child mortality. ROC analysis serves as a tool to assess the accuracy of predictors like birth size and birth order by quantifying their sensitivity and specificity (Obuchowski and Bullen, 2018). This approach integrates predictive analytics into the study of public health, offering a deeper understanding of how individual factors contribute to child mortality risk. The framework emphasizes the relative predictive power of birth characteristics by comparing different predictors' Area Under the Curve (AUC) values. It situates them within a broader context of healthcare disparities and maternal health factors. This methodology provides a structured means to evaluate the effectiveness of targeted interventions to reduce child mortality.

The framework also incorporates Indonesia's unique socioeconomic and cultural context, recognizing the influence of maternal health practices, birth traditions, and healthcare accessibility on child mortality. This perspective aligns with Bronfenbrenner's ecological systems theory, highlighting the interaction between individual and environmental factors (Ogunniyi *et al.*, 2024). The study acknowledges that child mortality in Indonesia is not only influenced by biological determinants but also by external factors such as maternal age, birth spacing, healthcare infrastructure, and cultural norms. These elements underscore the importance of a holistic approach that integrates individual-level and systemic-level predictors into a cohesive model, ensuring the findings are contextually relevant to Indonesian healthcare policies.

This study's framework bridges critical gaps in child mortality research by emphasizing the application of advanced predictive analytics and context-specific data. Unlike traditional models, which often focus on singular or generalized predictors, this framework evaluates multiple determinants simultaneously to capture their collective impact. The innovative use of ROC analysis offers a more nuanced understanding of the predictive power of factors like birth size and birth order, which are often underexplored in public health literature. Furthermore, integrating

Indonesia-specific data addresses the limited applicability of global models to local contexts, enhancing the study's relevance and utility for policymakers. By aligning theoretical insights with practical applications, the framework aims to contribute to effective, evidence-based interventions to reduce child mortality in Indonesia. In this study, we analysed predictors of child mortality using secondary data from the 2017 IDHS and evaluated the predictive ability of birth size and birth order through ROC analysis.

Materials and Methods

Design

The cross-sectional design allows for examining data collected at a single point, providing a snapshot of the factors associated with child mortality in Indonesia. This approach is well-suited for identifying potential predictors and assessing their relationship with child mortality, using secondary data from the 2017 IDHS.

Sample and Data Collection

This study used secondary data from the 2017 IDHS. The IDHS utilized standardized questionnaires developed by the Demographic and Health Surveys (DHS) Program, including the Household Questionnaire, the Women's Questionnaire, and the Child Health Questionnaire. These instruments were adapted to the Indonesian context and pretested to ensure cultural relevance. The validity and reliability of the IDHS instruments are well established internationally, as they undergo rigorous methodological development and field testing. In Indonesia, the Ministry of Health implemented the survey in collaboration with the National Population and Family Planning Board and the Central Statistics Agency, ensuring high-quality and nationally representative data.

The study's population consisted of women aged 15-49, from whom data were collected using a multistage stratified random sampling technique. In the first stage, several census blocks (enumeration areas) were randomly selected using probability proportional to size from each stratum. In the second stage, 25 households were randomly selected from each chosen census block. This method ensured the sample was nationally representative and covered various geographic and social groups nationwide.

The total initial sample comprised 17,848 respondents. Data were collected by a team of 1,160 trained personnel responsible for administering the survey and ensuring data quality. The survey collected detailed information on various factors, including socioeconomic status, healthcare access, maternal and child health indicators, and more. A thorough data-cleaning process was conducted to ensure the integrity of the analysis. Incomplete responses and respondents' unanswered questions were carefully removed from the dataset. After this process, a final sample of 13,946 respondents was obtained, representing the core dataset used for analysis in this study.

Variables

The study investigated a range of independent variables to assess their impact on child mortality in Indonesia. These variables encompassed the child's age, gender, place of residence, parental education, and issues such as vaginal bleeding during pregnancy. Factors like the child's size at birth, antenatal care, and the mother's knowledge of danger signs during pregnancy were examined. The study classified children's ages into 0-24 months (coded 0) and 25-59 months (coded 1). Gender was recorded as male (coded 1) or female (coded 2), while residence was categorized as urban (coded 1) or rural (coded 2). Maternal education was divided into four levels: no schooling (coded 0), primary (coded 1), secondary (coded 2), and higher education (coded 3). Vaginal bleeding during pregnancy was noted as either yes or no, and the child's size at birth was categorized into six groups ranging from very large (coded 1) to unknown size (coded 8).

Further variables included antenatal care, which was classified as no (coded 0) or yes (coded 1), and the mother's knowledge of danger signs during pregnancy, also classified as no (coded 0) or yes (coded 1). Economic status was divided into five categories: poorest (coded 1), poorer (coded 2), middle (coded 3), richer (coded 4), and richest (coded 5). The number of births was categorized into three groups: 1-2 births (coded 0), 3-5 births (coded 1), and 6-13 births (coded 2). The timing of the child's initial access to the mother's nipple was dichotomized into immediate (coded 0) or delayed (coded 1). The dependent variable was the survival status of the child, with survival coded as 1 (yes) and non-survival as 0 (no).

Data analysis

Categorical variables were summarized using frequency distributions and percentages to analyze the predictors of child mortality in Indonesia, which provided a clear overview of their prevalence and distribution. Relationships between predictors and child mortality were examined using cross-tabulation and Chi-square tests. Significant predictors were identified through multivariable logistic regression, with a p-value threshold of <0.05 , and non-significant variables were excluded using backward elimination. The final model's predictive performance was evaluated using ROC curve, which plotted sensitivity versus specificity to assess accuracy and discriminative ability, providing insights into the model's effectiveness in predicting child mortality.

Results

Respondents' characteristics

Table 1 outlines the characteristics of the respondents (N = 13,946) and offers valuable insights into factors related to child mortality in Indonesia. The data reveal that a slight majority of the children were aged 25-59 months (53.4%), with a near-equal distribution between male (51.2%) and female (48.9%) children. The respondents' residence was almost evenly split between urban (49.8%) and rural (50.2%) areas. Educational attainment of the mothers varied, with a majority having secondary education (56.2%), while only a tiny fraction had no formal education (1.2%). Additionally, issues such as vaginal bleeding during pregnancy were reported by 45.3% of respondents, and a significant portion (54.7%) did not experience this complication.

Further data analysis shows that most children were of average size at birth (53.6%), with a notable proportion classified as larger than average (27.5%). Antenatal care was significantly

underutilized, with 85.4% of respondents reporting no such care. Knowledge of danger signs during pregnancy was more prevalent, with 65.7% of mothers aware of them. Economic status was diverse, with the wealth index ranging from the poorest (25.6%) to the richest (17.3%). Birth order data indicated that most children were first or second-born (64.2%), and the timing of initial breastfeeding showed that 57.6% of children were breastfed immediately after birth. The survival status of children was overwhelmingly positive, with 99.2% reported to be alive. This study only included one child per mother to clarify the analysis and avoid confusion. We chose the last-born child under five because the 2017 IDHS collects the most complete and detailed information about the most recent child, such as health, nutrition, and survival. Using the last-born child also helps reduce errors since mothers usually remember recent events better than older ones. These findings underscore the diverse demographic, socioeconomic, and health-related factors that play a role in child mortality, providing a foundation for targeted interventions and further research (table 1).

Table 1 Characteristic of the respondents (N=13946)

Variable	Frequency	%
Age of the child		
0-24 months	6498	46.6
25-59 months	7448	53.4
Sex of the child		
Male	7134	51.2
female	6812	48.9
Residence		
urban	6946	49.8
Rural	7000	50.2
Education level		
No education	166	1.2
Primary	3498	25.1
Secondary	7836	56.2
higher	2446	17.5
Problems during pregnancy: vaginal bleeding		
No	7622	54.7
Yes	6324	45.3
Size of the last child at birth		
Very large	704	5
Larger than average	3830	27.5
Average	7472	53.6
Smaller than average	1532	11
Very small	242	1.7
Don't know	166	1.2
Antenatal care: UKBM*		

No	11906	85.4
Yes	2040	14.6
Know the danger signs.		
No	4777	34.3
Yes	9169	65.7
Wealth index		
Poorest	3574	25.6
Poorer	2771	19.9
Middle	2668	19.1
Richer	2520	18.1
Richest	2413	17.3
Birth order		
1-2	8953	64.2
3-5	4538	32.5
5-13	455	3.3
When a child put to the breast		
immediately	8027	57.6
late	5919	42.4
Child is alive		
No	113	0.8
Yes	13833	99.2

*UKBM = Community health services

Predictors of child mortality

Table 2 outlines the bivariate analysis and cross-tabulation of the outcome variable against various covariates from the 2017 IDHS dataset, revealing important insights into factors influencing child mortality. The child's age showed no significant association with mortality, with both age groups (0-24 months and 25-59 months) presenting similar odds ratios (OR 0.94; 95% CI 0.65, 1.36; $p = 0.755$). Similarly, the sex of the child did not appear to influence survival outcomes, as the odds of mortality for male children were not significantly different from those of female children (OR 1.162; 95% CI 0.80, 1.68; $p = 0.428$). However, the place of residence presented a near-significant association, with children in urban areas showing a trend toward lower mortality odds than those in rural areas (OR 0.690; 95% CI 0.47, 1.00; $p = 0.052$).

Maternal education level emerged as a significant predictor of child mortality. Children born to mothers with no education had significantly higher odds of mortality compared to those whose mothers had higher education (OR 3.750; 95% CI 1.23, 11.34; $p < 0.001$). Additionally, primary education was associated with increased odds of mortality (OR 1.979; 95% CI 1.11, 3.51). Vaginal bleeding during pregnancy also showed a significant association, with children whose mothers experienced this complication having higher odds of mortality compared to those without such issues (OR 1.580; 95% CI 1.07, 2.33; $p = 0.020$).

Table 2 Bivariate analysis and cross-tabulation of the outcome variable versus the covariates in children using the 2017 Indonesia Demographic Health Survey (IDHS) dataset

Variable	Child is alive		OR	95%CI	p-value*
	No (n/%)	Yes (n/%)			
age of child					
0-24 months	51 (0.4)	6447 (46.2)	0.94	0.65,1.36	0.755
25-59 months	62 (0.4)	7386 (53.0)	Ref		
Sex of child					
Male	62 (0.4)	7072 (50.7)	1.162	0.80,1.68	0.428
female	51 (0.4)	6761 (48.5)	Ref		
Residence					
urban	46 (0.3)	6900 (49.5)	0.690	0.47,1.00	0.052
Rural	67 (0.5)	6933 (49.7)	Ref		
Education level					
No education	4 (0.0)	162 (1.2)	3.750	1.23,11.34	<0.001
Primary	45 (0.3)	3453 (24.8)	1979	1.11,3.51	
Secondary	48 (0.3)	7788 (55.8)	0.936	0.53,1.65	
higher	16 (0.1)		Ref		
Problems during pregnancy: vaginal bleeding					
No	74 (0.5)	7548 (54.1)	1,580	1.07,2.33	0.020
Yes	39 (0.3)	6285 (45.1)	Ref		
Size of a child at birth					
Very large	4 (0.0)	700 (5.0)	0.130	0.03,0.44	<0.001
Larger than average	22 (0.2)	3808 (27.3)	0.131	0.05,0.31	
Average	59 (0.4)	7413 (53.2)	0.181	0.08,0.40	
Smaller than average	17 (0.1)	1515 (10.9)	0.255	0.10,0.62	
Very small	11 (0.1)	394 (2.8)	Ref		
Antenatal care: UKBM					
No	98 (0.7)	11808 (84.7)	1,120	0.64,1.93	0.683
Yes	15 (0.1)	2025 (14.5)			
Knowing danger signs					
No	48 (0.3)	4729 (33.9)	1.422	0.97,2.06	0.064
Yes	65 (0.5)	9104 (65.3)	Ref		
Wealth index					
Poorest	48 (0.3)	3526 (25.3)	1,919	1.10,3.34	0.001
Poorer	20 (0.1)	2751 (19.7)	1.025	0.53,1.96	
middle	11 (0.1)	2657 (19.1)	0.583	0.27,1.24	
Richer	17 (0.1)	2503 (17.9)	0.957	0.48,1.87	
Richest	17 (0.1)	2396 (17.2)	Ref		
Birth order					
1-2	51 (0.4)	8902 (63.8)	0.168	0.09,0.30	<0.001
3-5	47 (0.3)	4491 (32.2)	0.307	0.17,0.55	
6-13	15 (0.1)	440 (3.2)	Ref		
When a child put to the breast					

immediately	73 (0.5)	7954 (57.0)	1.349	0.91.1.98	0.128
late	40 (0.3)	5879 (42.2)	Ref		

**p-value (chi-square)*

The size of the child at birth was another critical factor, with very large, larger-than-average, and average-sized children all demonstrating significantly lower odds of mortality compared to tiny children. Specifically, very large children had the lowest odds (OR 0.130; 95% CI 0.03, 0.44; $p < 0.001$). The wealth index also indicated economic disparities in child survival, with children from the poorest households showing significantly higher odds of mortality than those from the richest households (OR 1.919; 95% CI 1.10, 3.34; $p = 0.001$). Lastly, birth order was a strong predictor, with first and second-born children showing significantly higher odds of mortality than those who were sixth to thirteenth in birth order (OR 0.168; 95% CI 0.09, 0.30; $p < 0.001$). These findings underscore the importance of socioeconomic factors, maternal health, and birth characteristics in determining child survival in Indonesia.

Model of child mortality

The multivariate analysis of child mortality using the 2017 IDHS data highlights the significant influence of birth size and birth order on child survival. The size of the child at birth emerged as a critical predictor, with very large, larger-than-average, and average-sized children exhibiting significantly higher odds of mortality compared to very small children. Specifically, very large children had an odds ratio (OR) of 5.964 (95% CI: 1.698, 20.942; $p = 0.005$), while larger than average and average-sized children had ORs of 5.554 (95% CI: 2.284, 13.506; $p < 0.001$) and 3.922 (95% CI: 1.719, 8.949; $p = 0.001$), respectively. Even children who were smaller than average had a higher risk of mortality, with an OR of 2.887 (95% CI: 1.155, 7.214; $p = 0.023$) when compared to very small children who served as the reference group. These findings suggest that extremes in birth size, particularly very large sizes, are associated with a higher risk of mortality, underscoring the importance of monitoring and managing birth outcomes (table 3).

Table 3 Multivariate analysis of variables in the final model of child mortality using the 2017 Indonesia Demographic Health Survey (IDHS) dataset

Indonesia Demographic Health Survey (IDHS) dataset				
Variable	p-value	OR	95% CI	
			Lower	Upper
Size of a child at birth				
Very large	.005	5,964	1,698	20,942
Larger than average	.000	5.554	2.284	13,506
Average	.001	3.922	1,719	8,949
Smaller than average	.023	2.887	1.155	7.214
Very small	Ref	Ref	Ref	Ref
Birth order				
1-2	.000	5.209	2.861	9.483
3-5	.001	2.836	1.552	5.184
6-13	Ref	Ref	Ref	Ref

Note: the independent education level variable, a problem during pregnancy: vaginal bleeding, and wealth index were excluded from the model because the p-value was 0.428, 0.317, 0.194 > 0.05, respectively.

Birth order also played a significant role in determining child survival. Children who were first or second-born had significantly higher odds of mortality (OR 5.209; 95% CI: 2.861, 9.483; $p < 0.001$) compared to those who were sixth to thirteenth in birth order. Similarly, third to fifth-born children also faced increased mortality risk, with an OR of 2.836 (95% CI: 1.552, 5.184; $p = 0.001$). This pattern indicates that lower birth order is associated with higher mortality, potentially due to resource allocation, maternal health, or caregiving capacity. Notably, the education level, issues during pregnancy such as vaginal bleeding, and wealth index were excluded from the final model due to their p -values exceeding 0.05, suggesting that these factors were not significant predictors of child mortality when controlling for other variables. This emphasizes the critical impact of birth characteristics over socioeconomic and maternal health factors in this context (table 3).

The ROC curve analysis was employed to evaluate the predictive ability of the final model in determining child mortality in Indonesia, focusing on two key predictors: the size of the child at birth and birth order. The AUC measures the model's accuracy, with higher values indicating better discriminative power. In this study, the AUC for the birth order was 0.611, which suggests that this variable has a modest predictive ability, correctly classifying child mortality outcomes approximately 61% of the time. On the other hand, the child's size at birth had an AUC of 0.582, indicating a slightly lower predictive ability, with the model correctly classifying outcomes about 58% of the time (figure 1).

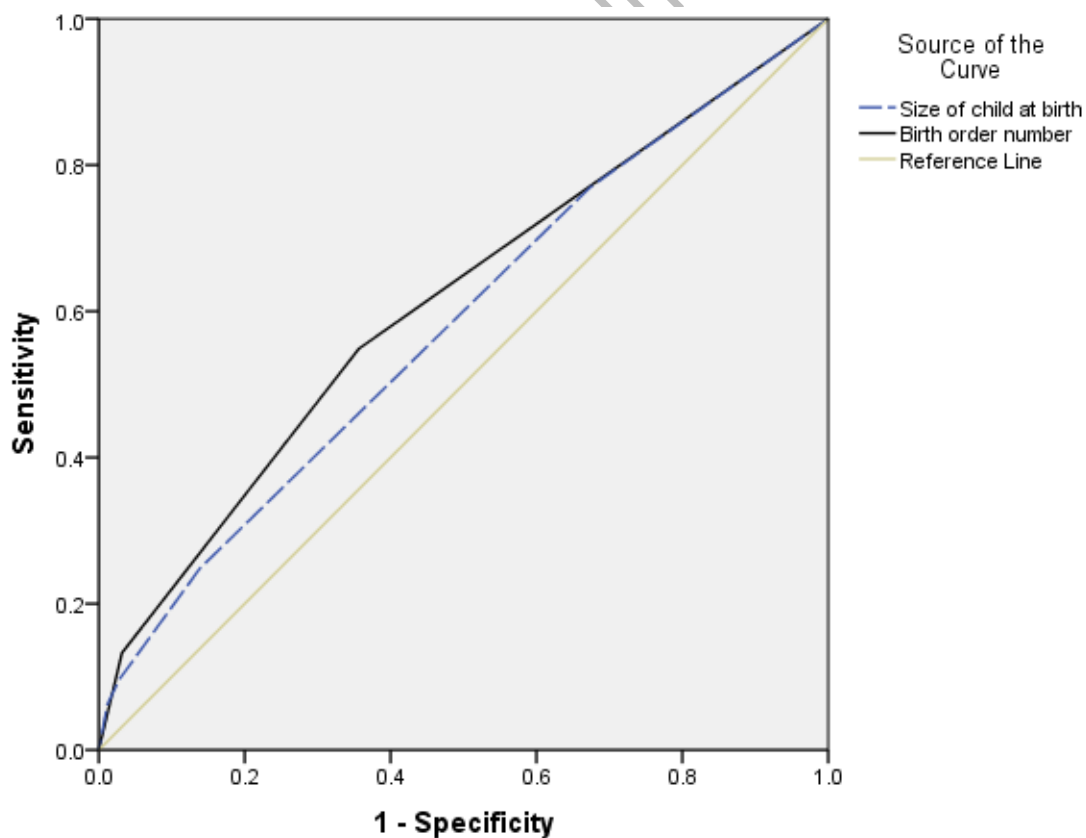


Figure 1 Receiver operating characteristics curve for the developed model on predictors of child mortality

These AUC values reflect the model's overall performance in predicting child mortality based on these two variables. Although both predictors demonstrate some ability to distinguish between children who survive and those who do not, the relatively moderate AUC values suggest room for improvement in the model's predictive power. The birth order appears to be a slightly stronger predictor than the child's size at birth, but neither predictor alone is highly accurate. These findings highlight the need to consider additional factors or refine the model further to enhance its ability to predict child mortality more precisely in the Indonesian context.

Discussion

Characteristics of the respondents

The findings from the respondents' characteristics in Table 1 provide a detailed view of the factors influencing child mortality in Indonesia. The near-equal distribution between male and female children and the balanced urban and rural residency suggests that gender and location might not be significant determinants of child mortality by themselves. However, these variables should still be considered in a broader analysis that includes other socioeconomic and health-related factors (Amegbor and Addae, 2023; Ahmed and Atiqul Haq, 2024; Hossain *et al.*, 2024).

Mothers' educational attainment emerged as a critical factor, with the majority having secondary education. This suggests that education is vital in child health outcomes, potentially affecting mothers' ability to access healthcare, understand health risks, and make informed decisions regarding their children's well-being (Khani Jeihooni *et al.*, 2022; Nishad and Sinha, 2023; Zhang *et al.*, 2024). The presence of pregnancy complications, such as vaginal bleeding, reported by 45.3% of respondents is another significant concern, highlighting the need for improved maternal healthcare services, especially during pregnancy (Seid *et al.*, 2023; Girchenko *et al.*, 2024).

The data on antenatal care utilization shows a glaring gap, with 85.4% of respondents reporting no antenatal care. This underutilization is alarming and points to potential barriers to accessing healthcare services, which could contribute to higher risks of child mortality. Additionally, the knowledge of danger signs during pregnancy, although relatively high at 65.7%, indicates that there is still a significant portion of the population that lacks critical awareness, which could delay seeking care and lead to adverse outcomes (Pai *et al.*, 2023; Tiruye and Shiferaw, 2023).

The economic disparities reflected in the wealth index show that child mortality risk may vary across different socioeconomic groups, with the poorest being potentially more vulnerable (Hossain *et al.*, 2024). The timing of initial breastfeeding and the survival status of children further reinforce the importance of immediate postnatal care and interventions (Rosenberg *et al.*, 2024). Overall, these results emphasize the need for targeted public health interventions that address education, access to maternal and child healthcare, and socioeconomic inequalities to reduce child mortality in Indonesia.

Predictors of child mortality

The bivariate analysis and cross-tabulation of factors influencing child mortality in Indonesia provide significant insights into the complex interplay of demographic, socioeconomic, and health-

related variables. One of the most striking findings is the non-significant association between child mortality and variables like the age and sex of the child. This suggests that, in this context, survival outcomes are not predominantly determined by these demographic factors but rather by other underlying conditions. However, the near-significant association between urban residence and lower odds of mortality highlights the potential influence of environmental factors, such as access to healthcare, sanitation, and other public health resources, often more readily available in urban settings (Girma *et al.*, 2023; Khan *et al.*, 2023).

Maternal education level stands out as a critical predictor of child survival, with the data clearly showing that children born to mothers with no formal education face significantly higher mortality risks. This finding underscores the pivotal role of maternal education in enhancing child health outcomes, likely due to better health literacy, improved utilization of healthcare services, and greater awareness of child-rearing practices (Oyekale and Maselwa, 2018; Yaya *et al.*, 2019; Ifada, Nurmalasari and Pramana, 2020; Balaj *et al.*, 2021). The strong association between maternal education and child survival suggests that public health interventions to improve women's educational opportunities could substantially reduce child mortality in Indonesia (Yaya *et al.*, 2018; Zhang *et al.*, 2024).

The analysis also highlights the importance of maternal health during pregnancy, as evidenced by the significant association between vaginal bleeding and increased child mortality. This finding emphasizes the need for enhanced prenatal care and monitoring, especially for high-risk pregnancies, to mitigate complications that could lead to adverse outcomes (Combellick *et al.*, 2024; Mekonnen *et al.*, 2024b). Additionally, the size of the child at birth and the birth order emerged as strong predictors of survival, with large children and those born early in birth order facing higher mortality risks. These findings highlight the importance of targeted interventions, such as improved maternal nutrition and family planning, to address these risk factors (Bango & Ghosh, 2023; Masquelier, Menashe-Oren and Reniers, 2023; Debere and Adjiwanou, 2024).

Economic disparities, as reflected in the wealth index, further complicate the picture of child mortality in Indonesia (Amini Rarani *et al.*, 2018; Yaya *et al.*, 2020). The higher odds of mortality among children from the poorest households compared to those from wealthier backgrounds suggest that socioeconomic inequalities play a crucial role in child survival (Amini Rarani *et al.*, 2018; Balaj *et al.*, 2021). This finding highlights the need for policies and programs that address these disparities by improving access to healthcare, nutrition, and other essential services for the most vulnerable populations. The research underscores the multifaceted nature of child mortality in Indonesia, driven by socioeconomic, health, and demographic factors. Addressing these issues through comprehensive public health strategies will be essential in reducing child mortality and improving overall child health outcomes in the country (Garcia *et al.*, 2023; Ghazy, Saidouni and Taha, 2024).

Model of child mortality

The multivariate analysis of child mortality from the 2017 IDHS offers critical insights into the factors significantly influencing child survival in Indonesia. The analysis reveals that birth size is a crucial determinant of mortality risk, with both very large and larger-than-average sizes associated with significantly higher odds of mortality compared to very small children (Kim *et al.*,

2022). Interestingly, while small size is often considered a risk factor, this analysis indicates that the extremes in birth size, particularly large or larger than average, pose an even greater risk. These findings may reflect complications associated with delivery or underlying health conditions in larger infants that necessitate careful monitoring and medical intervention (Memiah *et al.*, 2020). The strong association between birth size and mortality underscores the importance of prenatal care focused on monitoring fetal growth and ensuring appropriate measures are taken during delivery to manage potential complications (Yaya *et al.*, 2020; Chang *et al.*, 2021).

Birth order also emerged as a significant predictor of child mortality, with first and second-born children facing notably higher risks compared to those born later in the birth sequence. This pattern might be explained by parental inexperience, less developed maternal health during first births, or higher stress and resource strain in larger families that could disadvantage early-born children. However, the finding that first and second-born children are at higher risk suggests that targeted interventions aimed at new mothers, particularly in ensuring adequate health care and support, could be crucial in reducing early child mortality (Akinyemi *et al.*, 2018; Yaya *et al.*, 2018; Amir-ud-Din *et al.*, 2021). The exclusion of variables such as maternal education, vaginal bleeding during pregnancy, and wealth index from the final model is particularly notable. While these factors are often considered significant in other contexts, their lack of significance here suggests that, within this dataset, birth-related factors are more directly impactful on child survival outcomes than socioeconomic or maternal health variables when other factors are controlled. This finding challenges familiar assumptions and highlights the need for a more nuanced approach to understanding and addressing child mortality, emphasizing the role of birth characteristics as critical determinants (Yaya *et al.*, 2018).

The ROC curve analysis provides valuable insights into the predictive ability of the final model used to assess child mortality in Indonesia, specifically focusing on the variables of birth order and the child's size at birth. The AUC values indicate the model's capability to correctly classify child mortality outcomes, offering a metric of accuracy and discriminative power. In this study, the AUC for the birth order was found to be 0.611, indicating a modest predictive ability. This suggests that while the birth order can distinguish between survival and mortality outcomes to some extent, its effectiveness is limited, correctly classifying outcomes approximately 61% of the time. Similarly, the child's size at birth yielded an AUC of 0.582, reflecting an even lower predictive ability, with the model correctly classifying outcomes only 58% of the time.

These findings underscore a critical aspect of the model's performance: while birth order and birth size contribute to predicting child mortality, their predictive power is relatively modest. The AUC values, which are only slightly above 0.5, suggest that these variables alone are insufficient to build a highly accurate model for predicting child mortality. The relatively moderate performance of these predictors points to the complexity of factors influencing child survival, indicating that other variables not included in the final model may play a significant role. This highlights the potential for enhancing the model's accuracy by integrating additional predictors, such as maternal health indicators, socioeconomic status, access to healthcare, and environmental factors, which may provide a more comprehensive understanding of the determinants of child mortality (Lartey *et al.*, 2016; Akinyemi *et al.*, 2018; Warrohman *et al.*, 2018; Millogo *et al.*, 2019; Balaj *et al.*, 2021).

The analysis also raises important considerations for public health interventions in Indonesia. The modest predictive ability of birth order and birth size suggests that risk assessments should consider these factors. While the findings suggest that birth order and size at birth are significant predictors of child mortality, relying solely on these variables may not be sufficient to identify children at the highest risk of mortality accurately. Incorporating additional factors into the predictive model could enhance its precision and improve the identification of vulnerable children needing targeted interventions. Therefore, a multifaceted approach that includes a broader range of risk factors is necessary to improve the accuracy of predictions and, consequently, the effectiveness of interventions to reduce child mortality. This could involve a more detailed examination of maternal and child health data and better integration community-level factors to capture the diverse influences on child survival in Indonesia.

Overall, the study's results suggest that health interventions in Indonesia should prioritize improving prenatal and perinatal care, explicitly managing birth outcomes, and providing targeted support to new mothers, particularly those with first or second births. While addressing socioeconomic disparities remains essential, the findings indicate that immediate improvements in child survival could be achieved by focusing on birth-related risks and ensuring that maternal and infant health are closely monitored during the critical periods before, during, and after birth. This approach could help reduce child mortality rates more effectively and contribute to broader public health goals in Indonesia.

This study has some limitations that should be considered. First, because it uses cross-sectional data, it cannot establish transparent cause-and-effect relationships, highlighting the need for future longitudinal studies. Some variables, like birth size, rely on self-reported data, which may lead to recall or reporting bias. The study focuses on selected factors, such as birth order and size, but does not include others like environmental conditions or maternal health, which could also influence child mortality. The findings may not apply to all regions, as they are based on data from specific populations. Additionally, unmeasured factors, such as community health resources, may have influenced the results. Changes in healthcare access or socioeconomic conditions were not considered, and issues like missing or incomplete data might have affected the study's accuracy. Future research should address these limitations to guide effective interventions better.

Conclusion

In conclusion, this study highlights the modest predictive power of birth order and birth size in forecasting child mortality in Indonesia, as indicated by their AUC values. While these factors are essential, their limited ability to accurately predict outcomes underscores the complexity of child survival and the need for a more comprehensive model. It is crucial to integrate additional variables such as maternal health, socioeconomic status, access to healthcare, and environmental influences to improve predictions and interventions.

Public health strategies in Indonesia should prioritize enhancing prenatal and perinatal care, with a focus on managing birth outcomes and providing targeted support to mothers, particularly those with first or second births. Addressing these birth-related risks, alongside efforts to reduce socioeconomic disparities, could lead to significant improvements in child survival rates. By adopting a multifaceted approach that closely monitors maternal and infant health, Indonesia can make meaningful progress toward reducing child mortality and achieving broader public health objectives.

Data availability

The datasets generated by the survey research during and/or analyzed during the current study are available in the Dataverse repository (<https://drive.google.com/drive/folders/1GmhypqOagHsL4tjRSP930yoGSpDfoMhk?usp=sharing>)

Ethical Considerations

Compliance with ethical guidelines

This study adhered to ethical standards by utilizing datasets from the 2017 IDHS obtained through the DHS Program before the commencement of the research. The institutional review board approved the study, as documented in Authorization Letter 142047, confirming compliance with all ethical guidelines and protocols. The 2017 IDHS had already received ethical clearance from Indonesia's National Ethics Committee. Respondents were presented with an informed consent statement per these ethical standards before participating in any interviews or biomarker tests. This statement, read aloud to each respondent, allowed them the choice to participate or decline. For minors, a parent or guardian's consent was required before participation. The informed consent statement provided comprehensive details about the interview/test, including its purpose, the expected duration, procedures involved, potential risks and benefits, and contact information for further inquiries. Crucially, the statement emphasized the voluntary nature of participation, allowing respondents to refuse any questions, decline any tests, or withdraw from the study at any point. It also ensured that the respondent's identity and information would remain strictly confidential (<https://dhsprogram.com/Methodology/Protecting-the-Privacy-of-DHS-Survey-Respondents.cfm>). Access to the 2017 IDHS data was granted via the DHS Program's website at <https://dhsprogram.com/>.

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Authors contribution

Conceptualization: Yoyok Bkti Prasetyo; Data collection: Yoyok Bkti Prasetyo; Review and editing: Yoyok Bkti Prasetyo, and Sri Sunarigsih Ika Wardoyo; Writing the original draft. Final approval: All authors

Conflict of interest

The authors declared no conflict of interest.

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