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Social Determinants of Neonatal Health Outcomes in Indonesia: A Multilevel Regression Analysis

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Abstract

Indonesia's neonatal mortality rate remains alarmingly high. This study addressed the determinants of neonatal outcomes in Indonesia, including the effects of a decentralized health system, socioeconomic disparities, and geographic variations. The analysis used 2018 national survey data across 34 provinces, 513 cities/districts, and 300,000 households, with a sample of 73,864 women aged 10-54 years who have given birth in the preceding five years. The multilevel regression was used to assess the impact of social determinants and systemic inequalities on neonatal health. Key findings revealed a neonatal mortality rate that, despite being preventable in many cases, remained high with significant disparities. The final model, incorporating individual and community-level factors, reduced unexplained variance by 28% (PCV), with community factors explaining 16% of the variability (ICC 0.1600). The community-level risk variability also decreased, as shown by a reduction in the Median Odds Ratio from 2.43 to 2.13. These results highlighted the importance of targeting individual and community factors to reduce the risk of babies being born at risk. There is a critical need for targeted health policies and local-specific interventions to bridge the equity gap and improve neonatal health outcomes.

Keywords: disparities, Indonesia, multilevel regression, neonatal, social determinants

Introduction

Indonesia stands at a crucial juncture in its health trajectory as the 2005-2024 National Long-Term Development Plan nears its conclusion, paving the way for the new 2025-2045 era that focuses on achieving the ambitious "Golden Indonesia 2045" vision.[1–3] This vision hinges on resilient and competitive human capital and is anticipated to propel Indonesia from the middle-income trap toward economic prosperity. Hence, human capital investment is critical, and the country should start its development by investing in health and education. A healthy, well-educated population is a powerful driver of innovation, productivity, and overall economic well-being. This pivotal moment presents a golden opportunity to invest in the nation's most valuable asset – its people, especially the children, who will take over the nation in the era of 2045.[1]

Neonatal mortality, including stillbirths and maternal mortality, remains a substantial challenge for Indonesia despite significant progress concerning poverty reduction, education, and some health outcomes. The neonatal disorder has been one of the top ten mortality causes in the country for all ages since 1990.[4] Even though there is some improvement where the statistic decreased to 39.9% from 2008 to 2018, and its rank reduced from sixth to ninth, much can be done to alleviate the issue.[4] The severity of the problem is further highlighted by the fact that neonatal disorders ranked second as a cause of premature deaths measured by years of life lost in 2018 before being reduced to third place that same year.[4–6]

In 2018, Indonesia's neonatal mortality rate (NMR) was 12.7 deaths per 1,000 live births, which is equal to 72,400 deaths.[7] Indonesia is ranked at the eighth highest neonatal death number in the world, with other Asian countries such as India, Pakistan, China, and Bangladesh also included in the top ten ranks.[8,9] Several efforts continue to be sought by most stakeholders to end the preventable deaths of infants and children under the age of 5 (the under-five), of which 60% of deaths occurred during the first 28 days of life. Although Indonesia has currently met the Sustainable Development Goal (SDG) targets for under-five children, infant, and neonatal mortalities, its NMR remains higher than

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that of Singapore, Malaysia, Thailand, and Vietnam, all of which have an NMR of less than 10 deaths per 1,000 live births.[10]

The emphasis on decentralization in Indonesia's public health system is crucial to understanding the slow progress and persistent disparities in NMRs across different regions.[11] Decentralization was instituted as a strategic response to Indonesia's diverse geographic, socioeconomic, and cultural landscapes, which started in 2001 and encompassed numerous islands and remote areas. By redistributing authority and resources from the central to local governments, decentralization aims to allow tailored health interventions that are more aligned with the specific needs of local populations.[12,13]

This shift is particularly significant in addressing the stark differences in health outcomes highlighted by the 2017 Indonesia Demographic Health Survey, where NMRs significantly varied between socioeconomic statuses and regions.[14] The disparities reveal that centralized policies may not adequately address local challenges, making a strong case for why decentralization could potentially enhance the effectiveness of health service delivery by bringing decision-making closer to the point of need.[11,15] Such local empowerment is intended to improve responsiveness, enable better allocation of resources, and ensure that health programs are culturally appropriate and effectively implemented.[13] Hypothetically, decentralization should improve local health service delivery where devolution is applied, in which the local governments have autonomy for financial resource allocation and managing the human resources for health. However, neonatal mortality, along with maternal mortality, remains the major problem for nearly two decades after decentralization.[12]

Specific interventions referring to international guidelines have been introduced before and after decentralization.[16] These include adding more primary health care (PHC), providing a midwife for each village, building village maternity huts, setting more PHCs with basic emergency obstetric-neonatal care (BEMONC) capacity, and public hospitals with comprehensive emergency obstetric-neonatal care (CEMONC) capacity, among others.[13] Social protection programs in Indonesia have also improved significantly. However, even with the improvements, approximately 20% of families require a loan to pay their normal delivery costs. On top of that, the utilization of non-contributory (subsidized) participants is much lower than that of contributory memberships (less than 5% compared to about 25%).[17]

Despite the decrease in catastrophic expenditures among the poor due to social health insurance, affordability is not the only barrier to the utilization of maternal-neonatal health services. The revised 2017 National Health Account indicates that out-of-pocket spending reduced from 55% in 2010 to about one-third of the total health expenditure in 2017, which was later further reduced by 4% point in 2020.[18] Health illiteracy, high non-medical costs across regions, and socioeconomic groups limit the demand.[19,20] Due to their vulnerabilities, women face severe challenges in accessing health care. Low access, utilization, and quality of services resulted in poor health outcomes reflected by the slow progress of maternal and neonatal mortality.[21]

To deliver the quality of basic essential services and ensure a better outcome, a good quality of inputs, processes, and outputs is needed. In addition, a strong health system will be required to achieve the expected outcomes. However, after examining the current conditions of the available facilities, most of them are concerning since the focus is primarily on the demand side, only a portion of it.[22] Other than that, there is a lack of information and studies on the supply-side contributions to the stagnant outcomes, let alone studies using a health systems approach. Due to the complexity of determining the causes of neonatal mortality, this study aimed to identify the key factors contributing to neonatal health outcomes at different levels. By using a multilevel regression, this study aimed to capture the underlying supply and demand side factors on neonatal health outcomes within the hierarchical dataset.

Method

This study used a cross-sectional analysis designed to identify the key drivers of the determinant factors of neonatal health outcomes and their relative indicators. The goal was to improve the quality of integrated health services to achieve the Universal Health Coverage targets by strengthening health systems in the decentralization era. The study employed a multilevel regression, incorporating individual, district, and provincial levels. This study utilized multiple secondary data sources from 2018, including the 2018 Indonesian Basic Health Research, Village Potential Data, and the National Socioeconomic Survey. These data sources provided a comprehensive and diverse sample size, covering key variables such as household income, education levels, urban-rural residence, and regional healthcare infrastructure, which collectively offer valuable district-level data. Although no complementary national surveys beyond these were available to enrich district-level data, the analysis was enriched by incorporating other available surveys, routine

reports, and health profiles. Table 1 details the utilization of each survey, outlining their specific contributions to the study.

Table 1. Source of Surveys for Each Level of Characteristics

Variables	Survey(s) Used
Neonatal Characteristics	Indonesian Basic Health Research
Maternal and Household Characteristics	Indonesian Basic Health Research and National Socioeconomic Survey
District and Provincial Characteristics	Village Potential Data, Indonesian Basic Health Research, and National Socioeconomic Survey

This study analyzed data from the 2018 Indonesian Basic Health Research, Village Potential Data, and National Socioeconomic Survey; all datasets have disaggregated data at the cities/district level. The 2018 Indonesian Basic Health Research and National Socioeconomic Survey data used the same census blocks and households in their sampling, which enabled the data merging at the household level and analyzed a weighted total sample of 80,648 women aged 10-54 years who had birth or miscarriage within the 5-year period before the interview in 2018. Neonatal and intermediate health outcomes were examined for 73,086 live births among children aged 0-59 months, observed across 513 municipalities in 34 provinces throughout Indonesia. The data represents the diversity of Indonesia's population, areas, residences, geography, and other socioeconomic and cultural dimensions.

This study applied multilevel logistic regression analysis to define the key drivers of a specific neonatal health outcome. This approach estimated the sizes of the effects involved while accounting for the hierarchical structure of the data, where individual-level factors (maternal characteristics) were nested within geographic units (districts or provinces). It allowed for the simultaneous examination of individual and contextual factors influencing neonatal health outcomes. The models identified the main drivers of neonatal health outcomes as the basis for further policy, investment, and implementation strategy to accelerate the target achievements.

Results

Figure 1 describes the process of how the sample was obtained. Out of the eligible 80,648 childbearing mothers (aged 15-49 years who had a pregnancy in the last five years), 78,265 had live births, 1,912 had miscarriages, and 471 had stillbirths. Of the 73,086 observed live births, 24,372 were born prematurely, 2,476 were born with a low birth weight, and 523 had congenital anomalies.

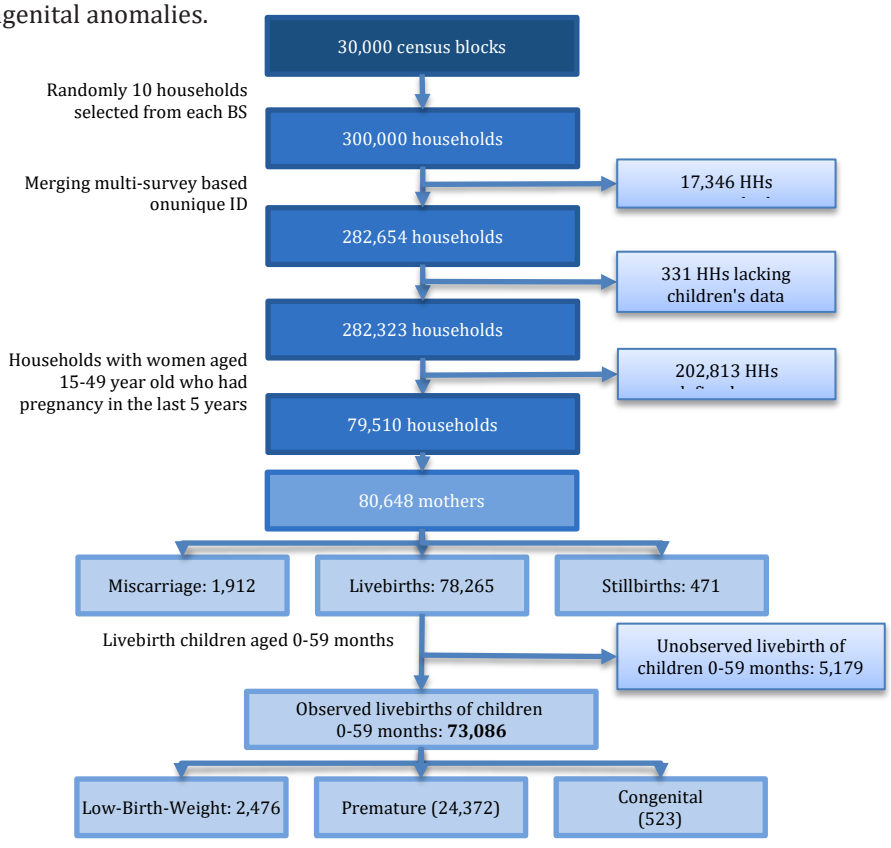

Figure 1. Sampling Tree

Table 2 presents around 17.06% of mothers had cesarean or other forms of delivery; about 8.6% of observed live births were from mothers who had their last births before age 21; 1.7% had unwanted pregnancies; 1.12% of mothers smoked; 1.6% had twins; 30.8% of the mothers experience pregnancy complications; 20.56% had complications during childbirth, and 3.48% had comorbidities. In addition, about half of mothers delivered at a health facility, even though skilled birth attendants assisted 98% of delivery.

The data set below was analyzed using a mixed-effects logistic regression model that examines various predictors' effects on neonatal health. The integration model used a multivariate adaptive Gauss-Hermite quadrature with seven integration points, a method suitable for handling non-nested random effects in logistic regression models (Table 3).

Table 2. Univariate Analysis of Neonatal, Maternal, District, and Provincial Characteristics

Variables	Obs.	
	Freq	(%)
Outcome		
Pregnancy outcomes		
Abortus	1,912	2.37
Stillbirths	471	0.58
Live birth	78,265	97.05
Total births	80,846	100.00
Neonatal outcomes		
Live birth	73,086	
Neonatal death	301	
Intermediate Outcomes		
Gestational age at birth	73,086	100
Pre-term	24,372	32,98
A-term	49,352	66.78
Post-term	179	0.24
Birth weight	73,903	100
Low Birth Weight	2,476	3.35
≥2,500 gram	71,427	96.65
Congenital disorders	73,903	
Blindness	64	0.09
Deafness	48	0.07
Speech impairment	75	0.10
Limb deficiency	116	0.16
Cleft lip	89	0.12
Down Syndrome	131	0.18
Newborn Conditions at Birth		
Sex		
Female	35,229	48.220
Male	37,857	51.80
Number of babies at birth		
Singleton	71,913	98.40
Twins	1,173	1.60
Birth Attendance		
Skilled Birth Attendance	66,416	90.87
Non-Skilled Birth Attendance	6,670	9.13
Institutional delivery		
Health facility	36,888	50.47
Home, etc.	36,198	49.53
Newborn Health Services		
Treatment for Low Birth Weight babies		
None	805	1.09
Incubation	1,003	1.36
Kangaroo Mother Care	574	0.78
Other to keep warm	94	0.13
Umbilical Cord Care	30,060	41.13
Received AB eye ointment	33,820	46.72
Neonatal visit coverage		
Postnatal Care 1	61,478	84.12
Postnatal Care 2	49,048	67.11
Postnatal Care 3	32,328	44.23
Proxy Quality of Postnatal Care 3	28,167	38.54
Mothers' Condition at Childbirth		
Age at the last childbirth		
Aged between 21-35	53,545	73.26
Aged <21 years	6,329	8.66
Aged >35 years	13,212	18.08
Complications during childbirth		
No complication	58,057	79.44

Variables	Obs.	
	Freq	(%)
Experienced complication	15,029	20.56
Delivery method		
Normal	60,620	82.94
Cesarean, etc.	12,466	17.06
Post-partum birth control	51,332	70.24
Mothers' Pregnancy Conditions		
Wanted/unwanted		
Wanted pregnancy	66,286	90.70
Wanted later pregnancy	5,540	7.58
Unwanted pregnancy	1,260	1.72
Experienced complications	22,540	30.84
Mother with comorbidities	2,540	3.48
Health Services During Pregnancy		
Antenatal Care		
Antenatal Care by Skilled Birth Attendants	69,866	95.59
≥4th times Antenatal Care	49,106	67.19
Proxy Quality of Antenatal Care		
<7 examination of 10 standards	14,563	18.56
≥7 examination of 10 standards	59,523	81.44
Mothers' Characteristic		
Mothers' education		
Higher education	9,869	13.50
High schools	40,468	55.37
Elementary school	15,793	21.61
Uneducated	6,956	9.52
Mothers' marital status:		
Union	71,296	97.55
Non-union	1,790	2.45
Mothers' employment		
Employed	32,781	44.85
Unemployed	40,305	55.15
Mothers' smoking habit		
Smoke	822	1.12
Ever smoked	707	0.97
Never smoked	71,557	97.91
Exposed as a passive smoker		
Yes, every day	29,025	39.71
Yes, sometimes	29,881	40.88
Never	14,180	19.40
Insurance ownership		
No insurance	26,530	36.30
Have insurance	46,556	63.70
Financing Source for Childbirth		
Insured	35,825	49.02
Out of Pocket	37,261	50.98
Financing source for referred services		
No need to be referred	58.057	
Not referred	6,857	
Referred cases	**8,172**	
Insured	5,456	66.76
Out of Pocket	2,716	26.63
Referral Systems		
Referral indication		
Referred	8,172	11.18
Not referred	6,857	9,38
No need to be referred	38,057	79.44
Time distance to Primary Health Care		
>1 hour	2,110	2.89
≤1 hour	70,976	97.11
Time distance to the nearest hospital		
>1 hour	19,243	26.33
≤1 hour	53,843	73.67
Households' Characteristics		
Residency		
Rural	43,232	59.15
Urban	29,854	40.95
Household size	73,086	
Expenditure per capita		
1st Poorest Quintile	14,643	20.04
2nd Quintile	14,592	19.97
3rd Quintile	14,617	20.00

Variables	Obs.	
	Freq	(%)
4th Quintile	14,703	20.12
5th Richest Quintile	14,531	19.88
Cities/Districts Characteristics		
Fiscal Capacity Index	513	100.00
Lowest	126	24.56
Low	128	24.95
Middle	126	24.56
High	89	17.35
Highest	44	8.58
Availability and accessibility of health facilities		
Doctor to population ratio	513	100.00
<1: 2,500 population	442	86.16
≥1: 2,500 population	71	13.84
Midwife to population ratio	513	100.00
<1: 1,000 population	267	52.05
≥1: 1,000 population	246	47.95
Primary Health Care to population ratio	513	100.00
<1: 16,000 population	263	51.27
≥1: 16,000 population	250	48.73
Number of hospitals by cities/districts	513	100.00
<1 hospital per city/district	15	2.92
≥1 hospital per city/district	498	97.08
Number of B/CEMONC by cities/districts	513	100.00
<1 CEMONC & 4 BEMONC	402	78.36
≥1 CEMONC & 4 BEMONC	111	21.64

*Pregnancy that was not initially wanted but eventually became wanted

The Wald Chi-square statistic of 692.63 with 40 degrees of freedom and a very small p-value (<0.000) indicated that the model fits and suggested that the variables included collectively had a strong predictive power. Conditional marginal effects were produced to estimate the change in the probability of the outcome associated with a one-unit change in predictor variables or a change from the base level for categorical variables that were mostly used in this data set.

Table 3. Multilevel Mixed-Effects Logistic Regression for Identifying Factors Associated with the Possibility of a Baby Being Born at Risk

a. Fixed Effect

Variables	Multivariate analysis*			
	Coefficient.	p-value >|z|	95% CI	
Neonatal Characteristics				
Sex				
Female				
Male	-0.0034	0.320	-0.0100	0.0033
Number of babies at birth				
Singleton				
Twin	0.2165	**0.000**	0.1903	0.2427
Birth order	-0.0029	0.054	-0.0059	0.0001
Mothers' Characteristics				
Age at the last childbirth				
Aged between 21-35 years				
Aged <21 years	0.0203	**0.002**	0.0075	0.0331
Aged >35 years	0.0079	0.114	-0.0019	0.0177
Exposed as a passive smoker				
No, never				
Yes, every day	-0.0005	0.923	-0.0102	0.0093
Yes, sometimes	-0.0077	0.111	-0.0172	0.0018
Intention to become pregnant				
Wanted pregnancy				
Wanted later pregnancy	0.0049	0.460	-0.0082	0.0180
Unwanted pregnancy	0.0455	**0.001**	0.0189	0.0721
Comorbidity				
Without comorbid				
With comorbid	0.0460	**0.000**	0.0276	0.0644
Pregnancy's complication				
Without complications				
Experienced complications	0.0305	**0.000**	0.0227	0.0382
Complications at childbirth				
Without complications				
Experienced complications	0.0190	**0.000**	0.0096	0.0285
Delivery method				
Normal		*(base group)*		
Cesarean, etc.	0.0157	**0.003**	0.0053	0.0261

Variables	Multivariate analysis*			
	Coefficient.	p-value >|z|	95% CI	
Insurance ownership				
Have insurance				
No insurance	0.0020	0.590	-0.0054	0.0094
Financing source for childbirth				
Insured				
Out of pocket	-0.0015	0.694	-0.0092	0.0061
Education				
Higher education				
High school	-0.0040	0.518	-0.0161	0.0081
Elementary school	0.0019	0.794	-0.0127	0.0166
Uneducated	0.0038	0.673	-0.0138	0.0214
Employment status				
Unemployed				
Employed	0.0087	0.023	0.0012	0.0161
Marital status				
Union				
Non-union	0.0012	0.9140	-0.0207	0.0231
Household Characteristics				
Region				
Java				
Sumatra	0.1178	**0.000**	0.0675	0.1680
Nusa Tenggara & Bali	0.0328	0.300	-0.0292	0.0948
Kalimantan	-0.0116	0.694	-0.0692	0.0461
Sulawesi	0.1209	**0.000**	0.0620	0.1799
Maluku Island	0.2084	**0.000**	0.1101	0.3067
Papua	0.0671	0.149	-0.0240	0.1583
Residency				
Urban				
Rural	-0.0002	0.973	-0.0090	0.0087
Household size	0.0014	0.197	-0.0007	0.0036
Expenditure per capita (log)	-0.0003	0.963	-0.0113	0.0108
Proportion of food expenses to total expenditure	-0.0001	0.822	-0.0006	0.0004
Head of Household Characteristics				
Sex				
Male				
Female	0.0073	0.207	-0.0040	0.0186
Education				
Higher education				
High school	0.0078	0.257	-0.0057	0.0212
Elementary school	0.0104	0.178	-0.0047	0.0255
Uneducated	0.0172	**0.040**	0.0008	0.0336
Employment status				
Unemployed				
Employed	-0.0007	0.918	-0.0137	0.0124
City/District Characteristics				
Fiscal capacity of the city/district	0.0049	0.351	-0.0095	0.0193
Percentage of ≥4th times Antenatal Care	-0.0016	**0.001**	-0.0025	-0.0007
Proportion of Health Exp to Gross Regional Domestic Product	-0.0009	0.523	-0.0036	0.0018
Proportion of Accredited Primary Health Care	-0.0005	0.315	-0.0013	0.0004
Proportion of Population with Poverty	-0.0009	0.552	-0.0039	0.0021
Proportion of Primary Health Care accessibility	-0.0014	0.167	-0.0035	0.0006
Proportion of Hospital accessibility	0.0009	0.128	-0.0002	0.0020
Average percentage of food expenditures	0.0022	0.159	-0.0009	0.0052
Supply side-readiness				
Availability	0.0237	**0.004**	0.0074	0.0400
Accessibility	-0.0084	**0.000**	-0.0129	-0.0040
Utilization	-0.0032	0.278	-0.0090	0.0026
Quality (proxy)	-0.0284	**0.000**	-0.0352	-0.0215
Pseudo R2		**0,048**		
Observation		**7308**		

b. Random Effect and Model Comparison for Factors Associated with Neonatal Risk

Parameter	Model 1 (Null Model)	Model 2 (Individual Level)	Model 3 (Community Level)	Model 4 (Full Model)
Intraclass Correlation Coefficient	0.2082	0.1708	0.1697	0.1600
Proportional Change in Variance	*Reference*	22%	22%	28%
Median Odds Ratio	2.43	2.19	2.19	2.13

Table 3 reveals multiple factors affecting health outcomes, particularly the probability of births under high-risk conditions. This variance suggested that geographic factors—such as healthcare infrastructure, service accessibility, and

regional socioeconomic conditions—played a significant role in shaping birth outcomes. The data supported targeted interventions at the municipal level to address disparities, suggesting that enhanced healthcare infrastructure, educational opportunities for mothers, and accessible, comprehensive prenatal care are critical in reducing neonatal risks. This analysis underlined the need for health policy frameworks that consider both individual and regional influences on neonatal health outcomes.

Four models were explored, each adding complexity by integrating individual and community factors to assess neonatal risks. The Null Model (Model 1), which excluded predictors, had an Intraclass Correlation Coefficient (ICC) of 0.2082, showing that 20.82% of risk variation was attributed to community-level differences. This high ICC highlighted the importance of community-level factors in neonatal outcomes. In the Individual-Level Model (Model 2), adding individual predictors like education and household income reduced the ICC to 0.1708, indicating that while community factors remain significant, individual factors also accounted for part of the risk, with a Proportional Change in Variance (PCV) of 22%.

The Community-Level Model (Model 3), focused on community-level predictors such as healthcare access, showed a slight reduction in ICC from 0.1708 to 0.1697. This implied that community factors alone explain the risk similarly to individual factors. Finally, the Full Model (Model 4), combining individual and community predictors, further reduced the ICC to 0.1600 and achieved the highest PCV (28%). The Median Odds Ratio (MOR) decreased from 2.43 in the Null Model to 2.13 in the Full Model, indicating a reduction in community-level variability and highlighting the effectiveness of the Full Model in providing a comprehensive understanding of neonatal risk. The Full Model thus captures the combined impact of both individual and community-level factors, offering a robust explanation of neonatal health risks.

These findings, based on the different models, suggested that policy initiatives should prioritize targeted interventions for at-risk groups and broader improvements in healthcare access and quality. Smoking cessation programs, support for unplanned pregnancies, and enhanced healthcare capacity and availability might reduce neonatal risk. Additionally, children's susceptibility to socioeconomic disparities, coupled with barriers to accessing quality healthcare, signified the importance of proactive healthcare support for expectant mothers. This data advocated community-specific health policies that address local socioeconomic disparities, promote comprehensive prenatal care, and strengthen healthcare accessibility to improve neonatal outcomes across regions.

Discussion

At the individual level, various biological and demographic factors significantly affect neonatal health outcomes. For instance, twin births increased the likelihood of neonatal risks by approximately 21.65%, emphasizing the inherent health challenges associated with multiple births.[23] Additionally, maternal age below 21 was associated with a 2.03% higher risk of adverse neonatal outcomes, underscoring the impact of young motherhood on neonatal health.[24,25] This is especially pertinent in Indonesia, where early marriage remains an issue, with 11.2% of women married before the age of 18 as of 2018. Early maternal age is generally linked with limited access to resources and health education, a critical consideration with potential adverse impacts on both maternal and neonatal health.[26,27]

Pregnancy complications also play a significant role in increasing neonatal risk, highlighting the importance of high-quality healthcare during critical periods. For mothers with pre-existing health conditions or complications during pregnancy, there was an additional 4.6% (p-value <0.000) risk increase for neonatal health issues.[28] Unplanned and unwanted pregnancies further elevated this risk by 5%, while cesarean deliveries presented a 0.8% higher probability of complications compared to natural births.[29] These findings suggest the need for comprehensive maternal healthcare that emphasizes managing pregnancy complications and providing adequate support for young or high-risk mothers. A well-rounded antenatal care (ANC) approach, with complete service coverage, can reduce neonatal risk by 1.1%, highlighting the importance of continuous and thorough prenatal care in improving outcomes.[30]

From a socio-environmental perspective, maternal employment has a minor association with neonatal risk (0.87%, p-value <0.02), which may relate to physical or emotional stress experienced during pregnancy.[31,32] Interestingly, while maternal education appeared to have limited direct impact, the educational level of the household head influences neonatal outcomes, with uneducated or less-educated heads increasing the risk by 1.7% (p-value <0.04).[33] This suggests that household awareness and understanding of health practices can be vital in prenatal care and health-seeking behavior. In comparison, the household head's employment status has a lesser impact on neonatal outcomes. In cities/districts with higher ANC rates (at least seven examinations), the neonatal risk was reduced by 0.16%, showcasing the importance of consistent and extensive maternal monitoring. This proves that enhancing access to ANC can mitigate

adverse neonatal outcomes and improve overall maternal and child health.[34]

The readiness of healthcare systems, indicated by a significant negative coefficient (-0.0388, p-value <0.000), was a strong predictor of improved neonatal outcomes. In particular, a greater supply-side readiness, reflecting availability, accessibility, and quality of healthcare services, reduces the risk of adverse neonatal outcomes.[35–37] Furthermore, cities/districts with higher percentages of accredited PHCs showed a 0.05% reduction in neonatal risk, and this emphasizes the importance of certified facilities that can ensure quality maternal and neonatal care.[35,38] These findings indicated that local healthcare infrastructure and service quality were crucial in reducing neonatal risks. The cities/district's healthcare environment directly impacted the birth outcomes, demonstrating that improving healthcare facility readiness and service accreditation can foster positive maternal and neonatal health outcomes.

This study revealed several data limitations, including insufficient neonatal death records and limited postnatal care information. This study relied on estimates from organizations like the United Nations Inter-Agency Group for Child Mortality Estimation and the Institute for Health Metrics and Evaluation, as local data on neonatal conditions like asphyxia or infections was unavailable due to inadequate data recording. This highlights the need for better data prioritization to enable effective policymaking in neonatal health. Comprehensive national surveys like Indonesian Basic Health Research are valuable for examining birth outcomes but lack detailed neonatal mortality data, limiting the analysis to service-related variables rather than postnatal outcomes. Therefore, this study suggests that neonatal health data should be prioritized in policy frameworks to effectively guide targeted interventions.

Conclusion

Despite limitations in data availability and reliability, this study provides valuable insights into the social determinants of health equity affecting neonatal outcomes in Indonesia. The findings highlight significant disparities influenced by maternal age, pregnancy planning, delivery methods, and municipal-level healthcare access. Younger mothers, unplanned pregnancies, and cesarean deliveries were associated with higher risks, underscoring the need for comprehensive family planning, maternal education, and informed medical decision-making. Geographic and economic barriers further limit healthcare accessibility, emphasizing the need for equitable policies that enhance healthcare quality, affordability, and utilization. Strengthening local data collection on neonatal mortality is essential to support evidence-based policymaking and improve maternal and neonatal health outcomes.

Abbreviations

NMR: neonatal mortality rate; SDGs: Sustainable Development Goals; PHC: Primary Health Care; CEMONC/BEMONC: Comprehensive Emergency Obstetric and Neonatal Care/Basic Emergency Obstetric and Neonatal Care; ICC: Intraclass Correlation Coefficient; PCV: Proportional Change in Variance; MOR: Median Odds Ratio; ANC: Antenatal Care.

Ethics Approval and Consent to Participate

This study has been approved by the Commission for Research Ethics and Public Health Service, Faculty of Public Health, Universitas Indonesia Number: Ket-38/UN2.F10.D11/PPM.00.02/2024.

Competing Interest

There are no significant competing personal, professional, or financial interests that may have influenced the performance or presentation of the work described in this manuscript.

Availability of Data and Materials

The data sources or information used as research materials are available from the national survey data.

Authors' Contribution

RS managed, analyzed data, and drafted the first paper. ACS provided the context of health policy and reviewed the paper.

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