PROVINCIAL DISPARITIES IN MATERNAL HEALTH: ANALYZING THE RELATIONSHIP BETWEEN ANTENATAL CARE VISIT, IRON SUPPLEMENTATION, AND MATERNAL HAEMORRHAGE IN INDONESIA

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ABSTRACT

Maternal mortality rate (MMR) is a key health measure. In Indonesia, maternal haemorrhage was a leading cause of maternal deaths in 2023. Comprehensive pregnancy care, including six antenatal visits (K6) and daily iron supplementation, is essential to ensure healthy pregnancies and reduce complications like haemorrhage. This study aimed to analyse the spatial distribution of maternal mortality due to haemorrhage in Indonesia and its correlation with antenatal care (K6) and iron supplementation (90 tablets). Spatial analysis was conducted using data from 38 provinces in Indonesia. Analysis was performed in ArcGIS with a bandwidth of 518.56 km and 999 permutations for sensitivity. Global Moran's I and Local Indicators of Spatial Association (LISA) were used to evaluate spatial autocorrelation and clustering. In 2023, maternal mortality due to haemorrhage in Indonesia was 23.12 per 100,000 live births. The highest incidence was in Papua Pegunungan, and the lowest in Jambi. Spatial analysis showed weak positive autocorrelation for maternal mortality (Moran's I = 0.089). Antenatal care K6 and iron supplementation showed strong positive spatial autocorrelation (Moran's I = 0.697 and 0.572). Bivariate analysis revealed negative spatial correlations between maternal mortality and both antenatal care K6 and iron supplementation. This study identified spatial clustering in maternal mortality due to haemorrhage, with weak positive spatial autocorrelation. Strong clustering was found for antenatal care K6 and iron supplementation, with better coverage in western provinces. Improving antenatal care and supplementation in underperforming regions could reduce maternal mortality due to haemorrhage.

***Keywords*:** Maternal mortality; Maternal haemorrhage; Antenatal care; Iron supplementation; Spatial analysis.

INTRODUCTION

The maternal mortality rate (MMR) becomes a key indicator for evaluating the effectiveness of maternity and child health programs. According to the 2020 Population Census, the MMR was measured at 189 per 100,000 live births, nearing The National Medium-Term Development Planning (RPJMN) goal of 183 per 100,000 live births. In 2023, there were 4,482 cases of maternal mortality, with maternal haemorrhage identified as the second leading cause (Kemenkes RI, 2024).

Effective care during pregnancy is needed for ensuring a healthy gestation, safe delivery, and rapid postpartum recovery, including the prevention of maternal mortality due to maternal

haemorrhage. Antenatal care and the giving of a minimum of 90 iron supplementations are effective interventions. Antenatal services encourage the early identification and management of antepartum haemorrhage , mitigating complications for both mother and fetus through quick intervention and referral (Mandal et al., 2023). Iron supplementation during pregnancy is important for preventing iron-deficiency anemia, hence decreasing the likelihood of maternal haemorrhage there by reducing mortality risk during childbirth (Juniarti, 2023)
The World Health Organization (WHO) encourages for a minimum of four antenatal care (ANC) visits during pregnancy; however, Indonesia has established a more rigorous guideline of six visits. This consists of at least one visit in the first trimester (0-12 weeks), two visits in the second trimester (12-24 weeks), and three visits in the third trimester (beyond 24 weeks until delivery), as well as a requirement for at least two assessments by a doctor during the initial visit in the first trimester and the fifth visit in the third trimester (Kemenkes RI, 2024) (WHO & USAID, 2018). This policy variations underscores the nation's dedication to enhancing maternal health, although it also prompts inquiries regarding the effects of these variations on health outcomes for mothers and newborns (Lattof et al., 2020). The WHO recommends for daily iron supplementation as a public health measure to enhance pregnancy outcomes and mitigate maternal anemia during gestation (WHO, 2012).

Indonesia attempts for national coverage to reduce maternal mortality rates, targeting 80% coverage for antenatal care K6 visit coverage and the distribution of iron supplementation for pregnant women, as documented annually in the Indonesian health profile for each province. The spatial diversity throughout 38 provinces in Indonesia presents unique problems and opportunities in reducing maternal mortality due to maternal haemorrhage. For an evaluation of maternal health, particularly maternal mortality due to maternal haemorrhage, and to formulate effective plans and policies, it is essential to understand the distribution and holistic management implemented to prevent maternal mortality due to maternal haemorrhage. This study aimed to spatial distribution of maternal mortality due to maternal haemorrhage and the correlation holistic management during antenatal care K6 visit coverage and iron supplementation coverage for pregnant woman (90 tablet).

RESEARCH METHODOLOGY

Study Area

This study was conducted in Indonesia, which has total area 1,892,410.09 km² in 2023. It is divided into 38 provinces. Geographical mapping of administrative areas with geographic coordinate was done assisted by Indonesia Geospatial. All these datasets used in this study are publicly available.

Study Design

Maternal mortality due to maternal hemorrhage was used as the dependent variable in this study. These data were collected Indonesian Health Profile Book 2023 and included 357 cases. The cases were calculated as the number of incidences per 100,000 live births. The independent variables were antenatal care K6 and iron supplementation coverage for pregnant woman (90 tablet).

METHOD

This study used spatial analysis to examine the spatial distribution of maternal mortality due to maternal haemorrhage and identify patterns and relationships between different geographic locations. The analysis was calculate the distribution of maternal mortality due to maternal haemorrhage across provinces using QGIS (version 3.32.2) and spatial relationships using LISA

(Local Indicator of Spatial Association) in GeoDa (version 1.22) to reveal clusters, trends, and correlations that may not be visible through traditional analysis methods.

This study used the Arc Distance (specify bandwidth was used 518.56 km) as weight to determine the relationship between one province and another. The 999 permutation was applied to assess the sensitivity of how significant provinces were to the number of permutations, with a significance level of $p < 0.05$. The Moran's I and p-value are used as a statistical measure to assess spatial autocorrelation, which examines whether nearby locations exhibit similar values for a particular variable. The Moran's I measure of spatial autocorrelation that ranges from -1 to 1. A positive Moran's I indicates positive spatial autocorrelation, meaning nearby locations have similar values. A negative Moran's I indicates negative spatial autocorrelation, where nearby locations have dissimilar values. Moran's I close to 0 suggests no spatial autocorrelation or spatial randomness. The p-value associated with Moran's I indicates the statistical significance of the spatial pattern observed. A small p-value (typically < 0.05) suggests that the observed spatial pattern is unlikely to have occurred by random chance alone, indicating significant spatial autocorrelation. A large p-value (typically > 0.05) suggests that the spatial pattern is not statistically significant, implying spatial randomness. In maternal mortality due to maternal haemorrhage per 100,000 live births in Indonesia, A Moran's I value close to +1 with a low p-value suggests significant spatial clustering of high or low maternal mortality due to maternal haemorrhage among provinces. A Moran's I value close to 0 with a high p-value indicates no significant spatial pattern, suggesting ANC visit rates are randomly distributed across provinces.

The Moran's I test is calculated as follows:

$$I = \frac{N}{W} \frac{\sum_{i=1}^{N} \sum_{j=1}^{N} w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{N}(x_i - \bar{x})^2}$$

Where *n* refers to the total number of spatial entities indexed by *i* and *j, i* represent the value of the *i*ts observation unit, denotes the mean of all the observation units, *wij* stands for the matrix of binary spatial weight or the strength of interaction between observation *i* and *j,* and *wij* =1 if they share a common border, or 0 otherwise, and it is the sum of all the observations (Gao, 2022).

A scatterplot in spatial analysis can be represented by four quadrants based on the standardized variables. These quadrants represent different patterns of spatial autocorrelation, with positive autocorrelation indicated by High-High (HH) and Low-Low (LL) correlations in upper right and lower left positions, and negative autocorrelation indicated by High-Low (HL) and Low-High (LH) correlation in the lower right and upper left positions.

As Global Moran's I is unable to give a correlation exact's location, Local Moran's I or Local Indicator of Spatial Associations (LISA) was developed, whose the formula is the following :

$$\frac{(x_i - \bar{x}) \sum jW_{ij} (x_j - \bar{x})}{s_i^2}$$

Where s_i^2 is the spatial weight matrix, i.e $\frac{\sum j \ (x_j - \bar{x})}{s_i^2}$, W*ij*; and N the number of maternal mortality spatial unit.

The LISA produce two types of maps, which are significance maps which represents the location shown by the Local Moran statistic at the significance $p<0.05$; and cluster maps, which classify the associated location (Htwe et al., 2023). From univariate maps, HH clusters show provinces with high maternal mortality surrounded by other high cases provinces, while LL cluster show low-case provinces surrounded by other high cases provinces. Bivariate maps

depict the patterns of factor interest where dark red represents HH areas (hot spots) and dark blue LL areas (cold spots); pink represents high-density areas surrounded by low-density areas (HL) and light blue represents low-density areas surrounded by high-density areas (LH) (Sandar et al., 2023).

RESULT

Maternal Mortality due to Maternal Haemorrhage by Province in Indonesia

Figure 1 displayed the Maternal Mortality due to Maternal Haemorrhage by Provinces in Indonesia, categorized by the number of mortality per 100,000 live births (displayed as 5 level, each in a different colour) among the provinces in Indonesia in 2023. The overall incidence of maternal mortality due to maternal haemorrhage was 23.12 per 100,000 live births. The highest incidence was found in Papua Pegunungan, with 250 mortality per 100,000 live births, while the lowest was in Jambi with 3.48 mortality per 100,000 live births. The quantile map indicated the top quintile (18.2 - 250 maternal mortality due to maternal haemorrhage per 100,000 live births) in 7 provinces, including Papua Pegunungan, Papua Barat, Maluku Utara, Maluku, Sulawesi Utara, Gorontalo and Sulawesi Tenggara.

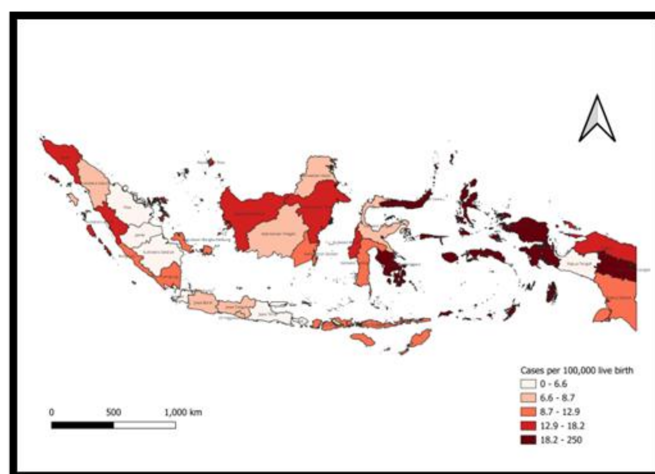

Figure 2 Maternal Mortality due to Maternal Hemorrhage per 100,000 live births in 2023

Spatial Distribution of Maternal Mortality due to Maternal Haemorrhage

Table 1 presented Moran's I value of maternal mortality due to maternal haemorrhage is 0.089 shows weak positive spatial autocorrelation with z-score 1.56 indicating that provinces with high or low maternal mortality rates due to maternal haemorrhage end to be geographically clustered with neighboring provinces that have similar value, although the effect is minimal.

Figure 2 presented that in the LISA analysis, no High-High or High-Low clusters were identified. A Low-Low cluster (cold spot) was observed in 10 provinces: Sumatera Barat, Kepulauan Riau, Kepulauan Bangka Belitung, Sumatera Selatan, Lampung, Banten, DKI Jakarta, Jawa Barat, Jawa Tengah, and DI Yogyakarta. Additionally, a Low-High cluster was identified in one province, Papua Tengah.

Spatial Distribution of Antenatal Care K6

Table 1 presented Moran's I value of antenatal care K6 is 0.697 shows strong positive spatial autocorrelation indicating that provinces with high or low antenatal care coverage 6 Visit tend to be geographically clustered with neighboring provinces that have similar values and spatially significant.

Figure 2 presented that in the LISA analysis, High-High (hotspot) was observed in 9 provinces: Riau, Jambi, Kepulauan Bangka Belitung, Sumatera Selatan, Lampung, Banten, DKI Jakarta, Jawa Barat, and Jawa Tengah. A Low-Low cluster (cold spot) was observed in 6 provinces: Maluku, Papua Barat, Papua Tengah, Papua, Papua Pegunungan and Papua Selatan. Additionally, a Low-High cluster was identified in one province: DI Yogyakarta. No High-Low clusters was identified.

Spatial Distribution of Number of iron supplementation coverage for pregnant woman (90 tablet)

Table 1 presented Moran's I value of iron supplementation coverage for pregnant woman (90 tablet) is 0.572 shows strong positive spatial autocorrelation indicating that provinces with high or low number of iron supplementation coverage for pregnant woman (90 tablet) tend to be geographically clustered with neighboring provinces that have similar value, although the effect is minimal and spatially significant.

Figure 2 presented that in the LISA analysis, High-High (hotspot) was observed in 11 provinces: Riau, Jambi, Bengkulu, Kepulauan Bangka Belitung, Sumatera Selatan, Lampung, Banten, DKI Jakarta, Jawa Barat, Jawa Tengah, and DI Yogyakarta. A Low-Low cluster (cold spot) was observed in 6 provinces: Maluku, Papua Barat Daya, Papua Barat, Papua Tengah, Papua and Papua Pegunungan. Additionally, a High-Low cluster was identified in one province: Papua Selatan. No Low-High clusters was identified.

Variables	Morans' I	p-value
Maternal Mortality due to Maternal Hemorrhage in 2023	0.089	0.074
Antenatal care K6 visit coverage	0.697	0.001
Iron tablet coverage for pregnant woman (90 tablets)	0.572	0.001

Table 1 Univariate analysis of The Variables

Variable	Moran's I	HH (no. of provinces)	HL (no. of provinces)	LL (no. of provinces)	LH (no. of provinces)
Maternal Mortality due to obstetric hemorrhage	0.074	0	0	10	1
Antenatal care K6 visit coverage	0.001	9	0	6	1
Iron tablet coverage for pregnant woman (90 tablet)	0.001	11	0	6	0

Table 2 Univariate Analysis of The Variables

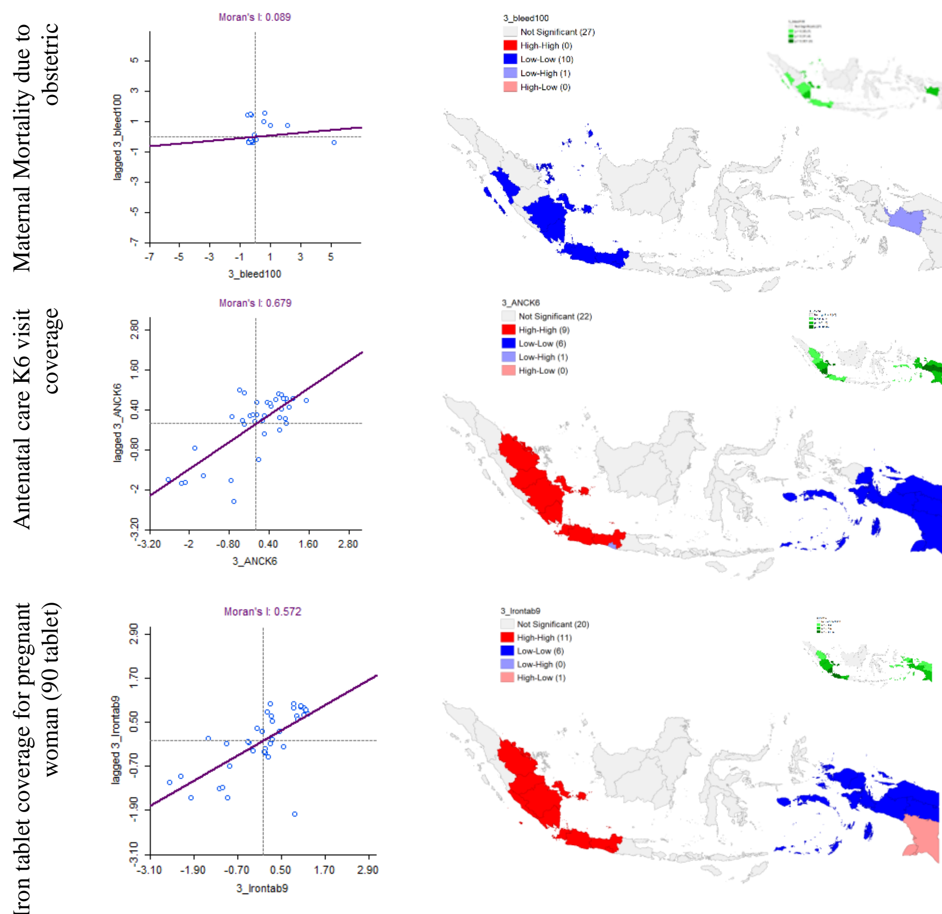

Figure 3 Univariate Analysis of The Variables

Bivariate Analysis of Antenatal Care K6 and Maternal Mortality due to Maternal Haemorrhage

This study analyzed the association between antenatal care K6 visit coverage and maternal mortality due to maternal haemorrhage. The study revealed that there was negative spatial correlation between antenatal care K6 visit coverage and maternal mortality due to maternal haemorrhage with Moran's I value -0.385 (table 3) and spatially cluster; HH Cluster in 1 province (DI Yogyakarta), HL Clusters in 9 provinces (Sumatera Barat, Kepulauan Riau, Kepulauan Bangka Belitung, Sumatera Selatan, Lampung, Banten, DKI Jakarta, Jawa Barat, and Jawa Tengah), HL Cluster in 1 province (Papua Tengah) (Table 4, Figure 3)

Bivariate Analysis of Iron supplementation coverage for pregnant woman (90 tablet) and Maternal Mortality due to Maternal Haemorrhage

This study analyzed the association between Iron supplementation coverage for pregnant woman (90 tablet) and maternal mortality due to maternal haemorrhage. The study revealed that there was negative spatial correlation between Iron supplementation coverage for pregnant woman (90 tablet) and maternal mortality due to maternal haemorrhage with Moran's I value -0.322 (table 3) and spatially significant; HL Clusters in 10 provinces (Sumatera Barat, Kepulauan Riau, Kepulauan Bangka Belitung, Sumatera Selatan, Lampung, Banten, DKI Jakarta, Jawa Barat, Jawa Tengah and DI Yogyakarta), HL Cluster in 1 province (Papua Tengah) (Table 4, Figure 3).

Variables	Morans' I	p-value
Antenatal care K6 visit coverage	-0.385	0.001
Iron tablet coverage for pregnant woman (90+ tablet)	-0.322	0.004

Table 3 Bivariat Analysis of Maternal Mortality due to Hemorrhage

Variable	Moran's I	HH (no. of provinces)	HL (no. of provinces)	LL (no. of provinces)	LH (no. of provinces)
Antenatal care K6 visit coverage	0.001	0	9	1	1
Iron tablet coverage for pregnant woman (90 tablet)	0.001	0	10	0	1

Table 4 Bivariat Analysis of Maternal Mortality due to Obstetric Hemorrhage

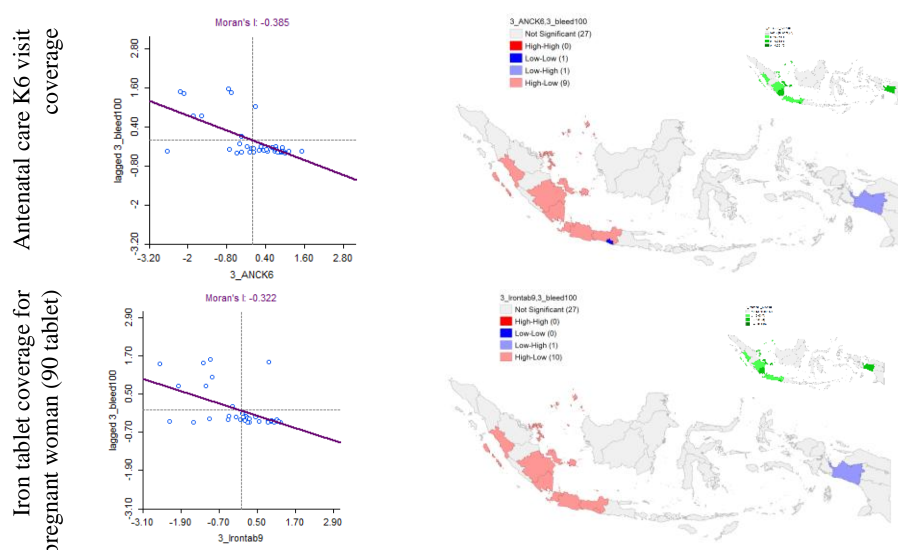

Figure 4 Bivariat Analysis

DISCUSSION

This study revealed that maternal mortality rates due to maternal haemorrhage was low in Western Indonesia, specifically in Java and a part of Sumatera, while increasing in some regions of Central and Eastern Indonesia. The univariate analysis results showed a positive Moran's I, indicating the occurrence of clustering. The results of the LISA showed that the low-low region (cold spot) of maternal mortality due to maternal haemorrhage is primarily found in various locations across Sumatera and Java. This result showed that obstacles remain in the effort to reduce maternal mortality due to maternal haemorrhage. This aligns with previous studies indicating that complex health issues remain in eastern Indonesia (Saifudin et al., 2024) (Tanlain et al., 2023).

The low maternal mortality rate due to maternal haemorrhage in Java and parts of Sumatera can be explained by several interrelated factors. First, better access to healthcare services in these regions significantly contributes to the reduction in maternal mortality rates. The research shows

that high coverage of antenatal care (ANC) services, including first and fourth visits, is closely associated with decreased maternal mortality (Christiawan, 2023). Additionally, the implementation of government programs, such as Indonesia Law No. 25 of 2004, which focuses on national development planning, has played a role in improving the quality of maternal healthcare services (Madani et al., 2022). Higher maternal education levels in Java and Sumatra also contribute to better understanding of reproductive health and the importance of antenatal care, thereby reducing the risk of complications during pregnancy and (Nataria et al., 2020). Lastly, the better socio-economic conditions in these regions, compared to other parts of Indonesia, enable mothers to access better healthcare services and reduce the risk of anemia, which is a significant risk factor for postpartum haemorrhage (Martha and Hayati, 2020)

The findings of the LISA univariate analysis highlighted provinces demanding attention to decreasing maternal mortality due to maternal haemorrhage. The provinces of Sumatra and Java identified regions with low mortality rates, compelling attention to the impact of national health policies and resource allocation on optimizing maternal health outcomes. In contrast, provinces with higher mortality rates (eastern Indonesia) necessitate focused initiatives to tackle root causes.

The univariate analysis results of antenatal care K6 showed that HH clusters (hotspots) were primarily located in Java and Sumatra, indicating elevated coverage levels in these regions. DI Yogyakarta provinces displayed HL clusters, indicating a lower coverage of antenatal care K6 visit coverage compared to its neighbouring provinces. Conversely, several provinces of Papua showed a relatively low antenatal care K6 visit coverage.

The Java and Sumatra islands are included several provinces, which have better healthcare infrastructure compared to other provinces in Indonesia. The availability of adequate healthcare facilities, such as community health centers (Puskesmas) and hospitals, along with higher accessibility, enables pregnant women to attend antenatal visits regularly (Sandalayuk et al., 2023) (Yuwana et al., 2022) Additionally, the level of education and public awareness about the importance of antenatal check-ups is higher in these areas, which contributes to the increase in visits (Armaya, 2018, Iryani, 2020).

On the other hand, social and cultural factors also play a significant role in the high coverage of antenatal visits in Java and Sumatra Islands. For instance, family and community support for pregnant women undergoing health check-ups has a strong influence (Armaya, 2018) (Suhadah et al., 2023). The research shows that pregnant women who receive family support tend to attend antenatal visits more regularly (Nurmasari and Sumarmi, 2019). Moreover, the presence of government programs supporting maternal and child health, such as education on the importance of antenatal care, also contributes to the increased coverage of visits in these two islands(Rahim, 2020) (Y, 2022). The combination of good healthcare infrastructure, higher educational levels, and strong social support are key factors explaining why Java and Sumatra islands have high antenatal care K6.

The univariate analysis results for iron supplementation coverage for pregnant women (90 tablets) revealed that HH clusters (hotspots) were predominantly located in Java and Sumatra islands, signifying elevated coverage of iron supplementation coverage for pregnant women (90 tablets) in these regions. In contrast, the Papua and Maluku regions exhibited low iron supplementation coverage for pregnant women (90 tablets), with the exception of South Papua. This province displayed an HL cluster, indicating a higher distribution of iron supplementation (90 tablets) for pregnant women compared to surrounding provinces.

This indicates that both regions not only have good access to healthcare services but also effective supplementation programs for pregnant women. The iron supplementation distribution program implemented by the government and health institutions in these areas has shown positive results, with pregnant women in Java and Sumatra islands being more compliant in consuming iron supplementation compared to those in other regions(Rahim, 2020). The research shows that compliance among pregnant women in consuming iron supplementation is closely related to their level of knowledge and positive attitudes toward health(Nurmasari and Sumarmi, 2019, Rahim, 2020).

Another factor supporting the high coverage of iron supplementation is the presence of intensive health campaigns and support from healthcare providers, was indicate that pregnant women who receive adequate information regarding the benefits of iron supplementation tend to be more compliant in consuming them (Nurmasari and Sumarmi, 2019, Rahim, 2020, Y, 2022). Furthermore, the existence of community-involved health programs, such as education and training for health cadres, also contributes to increased awareness and compliance among pregnant women regarding iron supplementation consumption (Laeliyah and Nadjib, 2017) (Rahim, 2020). The combination of effective health programs, support from healthcare providers, and community awareness are important factors explaining the high coverage of iron supplementation for pregnant women.

The low coverage of antenatal care K6 and iron supplementation in Eastern Indonesia is largely influenced by geographic and logistical challenges. Many regions in Eastern Indonesia are isolated, with inadequate infrastructure making it difficult for healthcare providers to reach pregnant women (Rukmini and Wibowo, 2022). This geographic barrier not only limits access to healthcare facilities but also impacts the availability of essential supplies, such as iron supplementation, which are crucial for maternal health. Research indicates that transportation issues significantly hinder access to care, particularly in remote areas where road conditions are poor (Muthalib and Purwanto, 2021).

Cultural beliefs and practices also play a critical role in the underutilization of ANC services and iron supplementation. Many communities hold traditional views regarding pregnancy and healthcare, which can create scepticism towards modern medical practices (Putri and Sari, 2023). For instance, some women may prioritize traditional medicine or rely on family advice over professional healthcare services. Studies show that increasing community awareness and education about the benefits of ANC and iron supplementation is essential for improving health-seeking behaviors among pregnant women (Sari and Kurniawati, 2020).

Additionally, socioeconomic factors, including poverty and low educational attainment, further exacerbate the issue. Many families in Eastern Indonesia face financial constraints that limit their ability to seek healthcare (Adriana and Santosa, 2022). Despite government efforts to provide free or subsidized services, indirect costs such as transportation and lost income can deter women from attending ANC appointments. Addressing these financial barriers and enhancing educational outreach could significantly improve the uptake of antenatal care K6 visit coverage and iron supplementation in the region.

Bivariate analysis indicated a negative spatial correlation between antenatal care K6 visit coverage and maternal mortality due to maternal haemorrhage. Provinces with higher antenatal care K6 showed lower maternal mortality due to maternal haemorrhage. This aligns with previous studies revealing that antenatal care can identify high-risk pregnancies and facilitate timely interventions; furthermore, antenatal care also reduces the likelihood of complication during labour. Pregnant women who access antenatal services also obtain health education and environmental support from healthcare professionals (Aryaneta, 2024) (Puspitasari et al., 2023).

Moreover, their findings indicated that women who received comprehensive antenatal care—including physical examination and psychiatric evaluation-exhibited reduced maternal mortality rates. Analysis of iron supplementation coverage for pregnant women (90 tablets) and maternal mortality due to maternal haemorrhage. Provinces with of iron supplementation coverage for pregnant women (90 tablets) showed lower maternal mortality due to maternal haemorrhage. This aligns with previous studies revealing that iron supplementation can significantly reduce maternal mortality due to maternal haemorrhage by addressing Iron Deficiency Anemia (IDA) and increasing overall maternal health (Weeks, 2024).

CONCLUSION

The study analysed maternal mortality due to maternal haemorrhage in various provinces of Indonesia, revealing spatial patterns and significant correlations with antenatal care K6 and iron supplementation coverage for pregnant women (90 tablets). The results indicate a positive spatial autocorrelation in maternal mortality rates, implying that areas with similar mortality rates are likely to cluster geographically. Cold spots with low death rates were identified in many regions, indicating the effectiveness of local programs that need further investigation. This research emphasizes the necessity for focused measures to improve antenatal care K6 and iron supplementation coverage for pregnant women (90 tablets). Policymakers can develop informed programs to reduce maternal mortality due to maternal haemorrhage across Indonesia by learn from the provinces with excellent outcomes for enhancing maternal health.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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