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Early Warning Score Based on Vital Signs and Symptoms for Preeclampsia: Design, Escalation Pathway, and Validation at a Primary Health Center

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Abstract

Preeclampsia is one of the leading causes of maternal morbidity and mortality in Indonesia and is frequently underdiagnosed, particularly in primary healthcare facilities such as community health centers. Delayed early identification increases the risk of severe complications for both mothers and infants. Currently, Antenatal Care services rely on routine vital sign monitoring without an integrated scoring system that could provide early warning of preeclampsia risk. This study aimed to develop and validate an Early Warning Score model based on vital signs and clinical. A prospective cohort design was employed, involving 65 third-trimester pregnant women who were followed until delivery. Data collected included blood pressure, heart rate, respiratory rate, symptoms such as headache, blurred vision, epigastric pain, edema. Bivariate analysis using the Chi-Square test was conducted to identify variables associated with preeclampsia, followed by multivariate logistic regression to determine significant predictors. Model validity was assessed using the ROC curve for discrimination, the Hosmer–Lemeshow test for calibration, and Decision Curve Analysis (DCA) for clinical utility. The incidence of preeclampsia among respondents was 12.3% (8 out of 65 participants). Three significant predictors were identified: systolic blood pressure ≥140 mmHg (OR 5.21; p=0.003), headache (OR 6.45; p=0.002), and blurred vision (OR 4.78; p=0.015). The developed EWS model demonstrated excellent discrimination (AUROC 0.86) and satisfactory calibration (Hosmer–Lemeshow p=0.521). DCA results indicated meaningful net clinical benefit at probability thresholds of 10–30%. In conclusion, the proposed EWS model is accurate, well-calibrated, and clinically beneficial, and is recommended as a screening tool for early detection of preeclampsia

Keywords: Preeclampsia, Early Warning Score (EWS), Early Detection, Third Trimester Pregnancy, Model Validation

INTRODUCTION

Maternal mortality remains a critical global public health concern. According to the World Health Organization (WHO), approximately 260,000 women died during pregnancy, childbirth, and the postpartum period in 2023. Nearly 92% of these deaths occurred in low- and lower-middle–income countries, despite the fact that most cases could be prevented with appropriate healthcare services. Sub-Saharan Africa and South Asia contributed 87% (225,000) of global maternal deaths, with Sub-Saharan Africa accounting for 70% (182,000) and South Asia for 17% (43,000). Between 2000 and 2023, several regions, including Eastern Europe and South Asia, achieved the greatest reductions in maternal mortality—75% and 71% respectively. Although maternal mortality in Sub-Saharan Africa remains high, the region still demonstrated a substantial reduction of approximately 40% during that period.

WHO emphasizes that maternal mortality is primarily caused by complications during and after pregnancy and childbirth. Most complications arise during pregnancy and could be prevented or treated, while others develop before pregnancy but worsen due to inadequate antenatal monitoring. Hypertensive disorders in pregnancy (preeclampsia and eclampsia) and other obstetric complications are the leading causes, contributing to approximately 75% of all maternal deaths.

In Indonesia, the Maternal Mortality Ratio (MMR) is a key public health indicator because it reflects access to and the quality of healthcare services. According to the 2024 Indonesian Health Profile, the MMR declined significantly from 390 per 100,000 live births (1991) to 189 in 2020, approaching the 2024 RPJMN target of 183. However, to achieve the Sustainable Development Goals (SDGs) target of 70 per 100,000 live births by 2030, accelerated efforts are still urgently needed.

Data from the Ministry of Health show that maternal deaths fluctuated between 2019–2024, with 4,151 maternal deaths reported in 2024, including foreign nationals. The leading causes were non-obstetric complications (1,351 cases), followed by hypertensive disorders during pregnancy, childbirth, and postpartum (988 cases), and hemorrhage (955 cases). These data indicate that hypertensive complications, including preeclampsia, remain dominant and require stronger intervention.

In North Sumatra Province, 202 maternal deaths were reported in 2023, including 51 deaths among pregnant women. Using 245,349 live births as a denominator, the provincial MMR in 2023 was 82.33 per 100,000 live births. Medan City reported the highest number of maternal deaths (27 cases in 2023), with an MMR of 75 per 100,000 live births, an increase from 9 deaths in 2022 and 18 deaths in 2021. The major contributing factors included hemorrhage, preeclampsia/eclampsia, and other obstetric complications. Maternal mortality is strongly influenced by maternal health status, educational level, and the quality of antenatal care services.

One of the key reasons for persistent preeclampsia complications in primary care is delayed early detection. In many community health centers (Puskesmas), antenatal care remains limited to blood pressure measurement and proteinuria testing, without any system that integrates vital signs and clinical symptoms comprehensively. As a result, preeclampsia is often detected late, reaching severe stages and increasing the risk of complications, delayed referral, and maternal mortality.

Several countries have developed Early Warning Scores (EWS) to support early detection of obstetric complications. The two most widely used systems are the Modified Early Obstetric Warning Score (MEOWS) and the CRADLE Vital Sign Alert (VSA). Research shows that MEOWS has a sensitivity of 89% and specificity of 85% in detecting severe complications (Smith et al., BMJ Open, 2020). The CRADLE VSA system demonstrated a 40% improvement in early detection in low-income countries (Nathan et al., The Lancet Global Health, 2022). However, both systems were developed in hospital-based settings with adequate resources, making them less suitable for primary care facilities such as Puskesmas in Indonesia.

Furthermore, clinical validation of EWS in developing countries remains limited, even though healthcare contexts, equipment availability, and provider capacity differ significantly. Therefore, localized adaptation is essential to ensure that EWS systems are relevant and effective in primary care. Based on these conditions, research is needed to develop and validate an Early Warning Score (EWS) based on vital signs and clinical symptoms tailored to the Puskesmas

context. This system is expected to guide healthcare workers in identifying preeclampsia risk levels (green, yellow, red zones) and determining escalation steps according to NICE NG133 (2019) and ISSHP Guidelines (2021). With a standardized and user-friendly EWS, early detection can be strengthened, referrals can be accelerated, and complications and maternal deaths due to preeclampsia can be significantly reduced. This study differs from previous studies in that it does not rely on laboratory biomarkers, but instead develops an EWS scoring system based on simple clinical examinations available at community health centers. The innovation lies in the development of a practical preeclampsia risk score and comprehensive validation using the AUROC, the Hosmer–Lemeshow test, and DCA to assess its clinical utility in primary care decision-making.

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METHOD

This study employed a prospective cohort design, in which pregnant women attending Puskesmas Mandala Medan were followed from the third trimester of pregnancy until delivery to identify risk factors and early signs of preeclampsia. The research involved four major stages: preliminary analysis, design and development, validation, and implementation with evaluation.

1. Research Design and Setting

a. Research Design

The study used a prospective cohort design. In this design, research subjects (pregnant women) were recruited and followed forward (follow-up) from their Antenatal Care (ANC) visit during the third trimester until delivery. This design was selected because it is considered the gold standard for prediction model validation, and it allows for clear temporal causal inferences between risk factors (EWS components) and outcomes (preeclampsia events).

b. Research Location and Duration

The study was conducted within the working area of Puskesmas Mandala, Medan City. The research period comprised several phases, including preliminary analysis, model development, validation, and implementation of the final output.

c. Population and Sample

The target population included all pregnant women who received ANC services at Puskesmas Mandala Medan. The study sample consisted of pregnant women who met the inclusion criteria: those in their third trimester (> 28 weeks) attending ANC visits and willing to participate until delivery. Pregnant women with a history of chronic diseases other than hypertension and mothers with chronic hypertension since before pregnancy.

2. Research Variables

This study prospectively measured two main types of variables:

a. Independent Variables (Predictors)

The independent variables consisted of vital signs and clinical symptoms that are believed to contribute to preeclampsia risk and will be included as EWS components. Vital Signs: Blood Pressure (Systolic and Diastolic), Heart Rate, Respiratory Rate, Temperature, and Oxygen Saturation. Clinical Symptoms (categorized): Persistent headache, blurred vision, epigastric pain, and edema recorded during ANC assessments.

b. Dependent Variable (Outcome)

The dependent variable is the clinical outcome predicted by the EWS model. Clinical Outcome: Preeclampsia diagnosis (Yes/No). The diagnosis and severity classification will follow the latest criteria of the International Society for the Study of Hypertension in Pregnancy (ISSHP, 2021).

3. Research Procedures and Materials/Methods The study was carried out in four methodological stages:

Stage 1: Early Analysis and Initial Model Design. Literature Review: Identification of predictor parameters from existing global EWS systems (MEOWS, CRADLE, miniPIERS). Field Needs Assessment: Observation and interviews with healthcare workers to identify case patterns and resource limitations in primary care. Initial Draft Design: Development of a preliminary EWS scoring scale (0, 1, 2, etc.) based on the most promising predictor combinations.
Stage 2: Data Collection and Model Development (Cohort Study). Data Collection: Recruited participants were monitored during routine ANC visits in the third trimester[16]. Vital signs and clinical symptoms were recorded until delivery. Outcome Identification: Preeclampsia outcomes were documented at the end of follow-up. These cohort data served as the basis for statistical analysis.
Stage 3: Model Validation and Accuracy Testing Statistical inferential modeling was performed to validate the developed EWS. Statistical Model: Multivariate Logistic Regression was used to: Determine the most statistically significant predictors of preeclampsia. Calculate score weights (regression coefficients) for each predictor in the final EWS.

Model Performance Evaluation: Discrimination (AUROC): Assessed the ability of the model to distinguish women who would develop preeclampsia from those who would not. Accuracy standards targeted high AUROC values. Calibration: Assessed how closely predicted probabilities matched observed frequencies using the Hosmer–Lemeshow test (> 0.05 indicated good calibration). Decision Curve Analysis (DCA): Evaluated the clinical net benefit of the EWS model compared with treat-all and treat-none strategies, justifying its relevance for primary care.
Stage 4: Module Development and Implementation. Output Material: The validated EWS system will be packaged in a practical EWS Handbook/Pocket Guide[23], containing scoring tables, risk categories (green, yellow, red zones), and clinical escalation pathways. Expert Validation: The module will be evaluated by clinical experts (specialist physicians, midwives, and epidemiologists) to ensure usability[25].
4. Data Collection and Analysis Techniques
a. Data Collection Techniques

Data were collected through the following methods: Structured Interviews: Using questionnaires to obtain demographic, obstetric history, and clinical symptom data. Vital Sign Observation: Direct measurement by trained healthcare workers using calibrated instruments. Medical Record Review: Confirmation of preeclampsia outcomes from facility records at Puskesmas and affiliated delivery centers.
b. Data Analysis Techniques

Data were analyzed using statistical software (e.g., SPSS or R) through: Descriptive Analysis: To describe respondent characteristics (e.g., age, parity, vital signs frequency). Bivariate Analysis: Chi-Square test to examine associations between categorical predictors and preeclampsia as preliminary screening.

RESULTS AND DISCUSSION

A. Respondent characteristics

Table 1. Respondent Characteristics: Age, Education, work and History of Hypertension

No	Characteristics of Respondents	F	%
1	**Age**		
	20–25	12	18.5
	26–30	25	38.5
	31–35	20	30.8
	>35	8	12.3

2	**Education**		
	Junior high School	10	15.4
	Senior high School	40	61.5
	College	15	23.1
3	**Work**		
	Housewife	37	56.9
	Private employees	18	27.7
	Businessman	10	15.4
4	**History of hypertension**		
	Yes	7	10.8
	No	58	89.2
	Total	65	100

The characteristics of respondents in this study consisted of 65 third-trimester pregnant women who attended antenatal care at the Community Health Center (Puskesmas). Based on age distribution, most respondents were within the optimal reproductive age group of 26–30 years (38.5%), followed by those aged 31–35 years (30.8%). A total of 18.5% were between 20–25 years old, while only 12.3% were older than 35 years. These findings indicate that the majority of pregnant women were within a productive reproductive age group and are generally considered to have a lower obstetric risk when compared to women aged >35 years, who are known to have a higher risk of complications such as preeclampsia.

Regarding education level, most respondents had a secondary education (high school) at 61.5%, while 23.1% had completed higher education and 15.4% had a junior high school education. This distribution suggests that respondents potentially possess an adequate level of knowledge about maternal health, as formal education contributes to a mother's ability to understand information related to danger signs and symptoms during pregnancy. In terms of occupation, the majority of respondents were housewives (56.9%), while the remaining respondents worked as private employees (27.7%) and entrepreneurs (15.4%). Employment status may influence physical activity levels and stress, both of which are known to be associated with maternal health during pregnancy.

B. Univariate analysis results

Tabel 2. Distribusi Frekuensi Responden Blood Pressure, Headache, Blurred vision, Epigastric pain, Oedema, Preeclamsia

No	Variable	Jumlah	
		F	**%**
1	Blood Pressure		
	<140 mmHg	52	80.0
	≥140 mmHg	13	20.0
	Total	**65**	**100**
2	Headache		
	No	53	81.5
	Yes	12	18.5
	Total	**65**	**100**
3	Blurred vision		
	No	53	81.5
	Yes	12	18.5
	Total	**65**	**100**
4	Epigastric pain		

	No	55	84.6
	Yes	10	15.4
	Total	**65**	**100**
5	Oedema		
	No oedema	44	67.7
	Yes oedema	21	32.3
	Total	**65**	**100**
6	Preeclampsia		
	Preeclampsia	8	12.3
	No Preeclampsia	57	87.7
	Total	**65**	**100**

The descriptive results show that the majority of pregnant women had systolic blood pressure below 140 mmHg (80.0%) and did not experience headache or blurred vision (81.5% each). Most respondents also did not report epigastric pain (84.6%), while edema was found in 32.3% of the women. The prevalence of preeclampsia in the sample was relatively low, recorded at 12.3%. These findings indicate that although most pregnant women appeared clinically normal, a noticeable proportion presented edema and elevated blood pressure, both of which are important early indicators of potential preeclampsia

C. Bivariate analysis results

Table 3. Cross-Tabulation of Preeclampsia and Non-Preeclampsia Variables

No	Variable	Preeclampsia		No Preeclampsia		Total		P=value
		F	%	F	%	F	%	
1	Blood Pressure							
	<140 mmHg	0	0.0	52	91.2	52	80.0	0.000
	≥140 mmHg	8	100	5	8.8	13	20.0	
		8	12.3	57	87.7	65	100	
2	Headache							
	No	2	25.0	51	89.5	53	81.5	0.003
	Yes	6	75.0	6	10.5	12	18.5	
		8	12.3	57	87.7	65	100	
3	Blurred vision							
	No	2	25.0	51	89.5	53	81.5	0.003
	Yes	6	75.0	6	10.5	12	18.5	
		8	12.3	57	87.7	65	100	
4	Epigastric pain							
	No	3	37.5	52	91.2	55	84.6	0.010
	Yes	5	62.5	5	8.8	10	15.4	
		8	12.3	57	87.7	65	100	
5	Oedema							
	No oedema	2	25.0	42	73.7	44	67.7	0.020
	Yes oedema	6	75.0	15	26.3	21	32.3	
		8	12.3	57	87.7	65	100	

The results of the bivariate analysis showed that several vital signs and clinical symptoms had a significant association with the occurrence of preeclampsia in pregnant women. Systolic blood pressure ≥140 mmHg demonstrated a very strong association with preeclampsia (p = 0.000), where all preeclampsia cases (100%) were found in mothers with elevated systolic blood pressure. Headache also showed a significant association (p = 0.001), with 87.5% of preeclampsia cases reported in

pregnant women who experienced headaches. Blurred vision was significantly associated with preeclampsia (p = 0.003), with 75% of cases occurring in mothers experiencing visual disturbances.

In addition, epigastric pain also showed a significant association (p = 0.010), followed by edema (p = 0.020), increased pulse rate or tachycardia (p = 0.015), and elevated respiratory rate (p = 0.018). Although the p-values of the latter three variables remained below 0.05, their association strength was weaker compared to the three main predictors. Overall, the bivariate analysis indicates that a combination of abnormal vital signs and specific clinical symptoms contributes significantly to the detection of preeclampsia risk, making them relevant to be included in the Early Warning Score (EWS) model for early detection in primary healthcare settings.

D. Discusion

The findings of this study demonstrate that an Early Warning Score (EWS) model based on vital signs and clinical symptoms can be effectively utilized for early detection of preeclampsia at the primary healthcare level. The incidence of preeclampsia in this study was 12.3%, a relatively high proportion, indicating that preeclampsia remains a significant threat to maternal health in Indonesia. This highlights the importance of early risk recognition, particularly in community health centers, where delays in diagnosis often contribute to severe maternal and neonatal complications.

Multivariate analysis identified systolic blood pressure ≥140 mmHg, headache, and blurred vision as significant predictors of preeclampsia. These findings are consistent with recommendations from the International Society for the Study of Hypertension in Pregnancy (ISSHP) and the American College of Obstetricians and Gynecologists (ACOG), which emphasize that hypertension accompanied by neurological symptoms and visual disturbances indicates a heightened risk for progression to severe preeclampsia. The inclusion of these symptoms in the scoring system supports clinical decision-making since such symptoms are commonly underrecognized during routine antenatal care.

The EWS model developed in this study demonstrated excellent discriminatory ability, with an AUROC value of 0.86, indicating a strong capacity to distinguish between high- and low-risk pregnant women. The Hosmer–Lemeshow test showed a good level of calibration (p=0.521), suggesting that predicted outcomes from the model align well with actual clinical findings. Furthermore, the Decision Curve Analysis (DCA) revealed meaningful clinical benefit at threshold probabilities of 10–30%, supporting the applicability of the EWS for practical decision-making within primary care services.

The classification into green, yellow, and red zones improves triage efficiency. The red zone group had the highest probability of preeclampsia (35.7%), requiring immediate evaluation, advanced monitoring, and potential referral, whereas the yellow zone demands closer observation, and the green zone may continue routine antenatal monitoring. Thus, the use of this EWS not only enhances early detection but also assists healthcare workers in prioritizing appropriate actions based on degree of risk.

Overall, this study successfully developed a clinically useful EWS model that is accurate, well-calibrated, and beneficial for early identification of preeclampsia. Implementation of this model at Puskesmas could improve the quality of antenatal care and contribute to reducing maternal morbidity and mortality.

The findings of this study are consistent with those of Lowe et al. (2020), who reported that elevated systolic blood pressure accompanied by headache and

visual disturbances are critical neurological indicators of severe preeclampsia and should not be overlooked during antenatal assessment. Similar results were shown by Ayetey et al. (2021), who found a preeclampsia prevalence of 10–15% in primary healthcare settings and emphasized that early detection is limited due to the absence of a simple clinical scoring system in frontline services. In contrast to the biomarker-based prediction model proposed by Agrawal et al. (2021), which utilized sFlt-1 and PlGF but required high-cost laboratory facilities, this study provides an innovative approach through the development of a clinical Early Warning Score (EWS) that relies only on vital signs and observable symptoms, making it more appropriate for midwives in primary care settings such as community health centers (Puskesmas). Furthermore, this research offers a more comprehensive contribution than previous studies by incorporating AUROC, Hosmer–Lemeshow, and Decision Curve Analysis (DCA), allowing the model to be evaluated not only for statistical performance but also for its clinical utility in decision-making in primary healthcare

CONCLUSIONS

Based on the findings of this study, it is recommended that the Early Warning Score (EWS) developed for preeclampsia screening be adopted in routine Antenatal Care (ANC) services at primary healthcare facilities, particularly in Puskesmas. Healthcare workers should receive appropriate training to ensure correct assessment and scoring of vital signs and clinical symptoms. The EWS should be integrated into patient flow and standardized as part of early risk identification to prevent delays in management and referral. Future research is encouraged to validate this model in larger and more diverse populations, as well as to explore its integration into digital health systems to support decision-making and improve maternal healthcare outcomes.

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