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DIGITAL ELECTRONIC EARLY WARNING SCORES FOR EARLY DETECTION OF PATIENT DETERIORATION AND NURSING RESPONSE: A SYSTEMATIC LITERATURE REVIEW

Nawawi*, Wastu Adi Mulyono
Master of Nursing, Universitas Jenderal Soedirman, Jl. Prof. Dr. HR. Boenyamin No. 708, Bobosan, Purwokerto Utara, Kabupaten Banyumas, Jawa Tengah 53143, Indonesia
*nawawirswk@gmail.com

ABSTRACT
Early recognition of patient deterioration and prompt clinical intervention are essential components of quality healthcare and patient safety. Digital-based Electronic Early Warning Score (E-EWS) systems have been developed to facilitate the early identification of clinical deterioration; however, evidence regarding their effectiveness remains inconclusive. This systematic review aimed to examine the role of digital E-EWS systems in enhancing the early detection of patient deterioration and improving nursing responses across various clinical settings. A systematic review was conducted in accordance with the PRISMA 2020 guidelines. Relevant studies published between 2015 and 2025 were retrieved from PubMed, PMC, Scopus, Google Scholar, Springer, and MDPI databases. The search strategy employed the following keywords: ("Electronic Early Warning Score" OR "digital early warning system") AND ("patient deterioration" OR "early detection") AND ("nursing response" OR "rapid response" OR "escalation") AND (inpatient OR hospital OR ward). A total of 133 articles were initially identified, and after screening based on PICOS criteria, nine studies met the eligibility criteria and were included in the final analysis. The selected studies evaluated the impact of E-EWS implementation on early detection of patient deterioration, clinical processes, nursing responses, and patient outcomes. The findings demonstrated that digital E-EWS systems improved the accuracy and completeness of vital sign documentation, enabled earlier identification of high-risk patients, and strengthened clinical escalation through automated alerts and standardized response recommendations. Improvements in nursing practice were also observed, including increased monitoring frequency, enhanced interprofessional communication, and more timely activation of Rapid Response Teams (RRT). Nevertheless, evidence regarding major clinical outcomes, such as mortality, cardiac arrest, and unplanned intensive care unit (ICU) admissions, remained inconsistent across studies. Variability in study design, differences in E-EWS platforms, and limited reporting of nursing interventions posed challenges to establishing definitive conclusions. Overall, digital E-EWS systems demonstrate considerable potential to improve patient safety and support the quality of nursing care in contemporary healthcare settings.

Keywords: digitalization of early warning systems; early detection of patient deterioration; electronic early warning score (e-ews); nursing response; patient safety

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INTRODUCTION

Predicting, preventing, and providing rapid responses to patient deterioration are crucial aspects of improving hospital safety. Undetected clinical deterioration is one of the leading causes of unplanned transfers to the intensive care unit (ICU), which are often associated with prolonged length of stay and higher mortality rates compared to patients admitted directly to the ICU from the emergency department (Mphil et al., 2024). Approximately 10% of hospitalized patients are at risk of experiencing adverse events, and around 30% of these incidents may result in fatal outcomes. Most unexpected incidents occur in general wards, and more than half are actually preventable (Lee & Hong, 2019; Sasmito et al., 2024).

Serious clinical deterioration events can be minimized if changes in vital signs are recognized and managed promptly (Albutt et al., 2016). Although vital signs can identify patients at risk, delays in

response still frequently occur and are known as “failure to rescue,” which may result from various factors (Subbe et al., 2017). One of the main causes is the failure of healthcare professionals to recognize warning signs, accompanied by a lack of preventive action before the patient’s condition deteriorates further (Lee & Hong, 2019).

Before patients experience clinical deterioration, changes in vital signs generally appear and can be detected. In 1997, the Early Warning System (EWS) was introduced as a method to systematically monitor these changes (Lee & Hong, 2019). This system assigns scores based on vital parameters such as respiratory rate, heart rate, blood pressure, oxygen saturation, and level of consciousness. The higher the resulting score, the worse the patient’s clinical condition (Lee & Hong, 2019). When the score reaches a certain threshold, the system triggers a clinical response to prevent further deterioration (Lyons et al., 2019). Since being adopted as part of patient safety programs, EWS has developed rapidly and its use has expanded across various countries (Lee & Hong, 2019; Mphil et al., 2024; Ye et al., 2019).

Technological advancements subsequently led to the development of digital-based Electronic Early Warning Score (E-EWS) systems designed to overcome the limitations of manual systems. These systems enable automatic recording of vital signs, real-time score calculation, consistent risk display, and the provision of visual alerts or alarms that assist nurses in responding according to clinical standards (David Chi-Wai, 2024; Id et al., 2019; Qaddumi, 2024). In several hospitals, the integration of E-EWS with Electronic Medical Records (EMR) has also accelerated the delivery of information to attending physicians and Rapid Response Teams (RRT) (Wu et al., 2021).

Nevertheless, scientific evidence regarding the effectiveness of digital E-EWS systems remains varied (Pullinger et al., 2016). Several studies have reported improvements in documentation compliance, reductions in delays in clinical response, and improvements in certain patient outcomes (Santi Widianti Kuswara, 2025; Wu et al., 2021). However, other studies have shown that the implementation of digital systems does not always produce significant effects on mortality, length of stay, or cardiac arrest rates, particularly among specific patient groups such as high-risk surgical patients (Id et al., 2019; Wong et al., 2024). These variations in findings indicate that implementation effectiveness is strongly influenced by organizational factors, information technology readiness, user competence, and the patient safety culture within each healthcare facility (Noya et al., 2025).

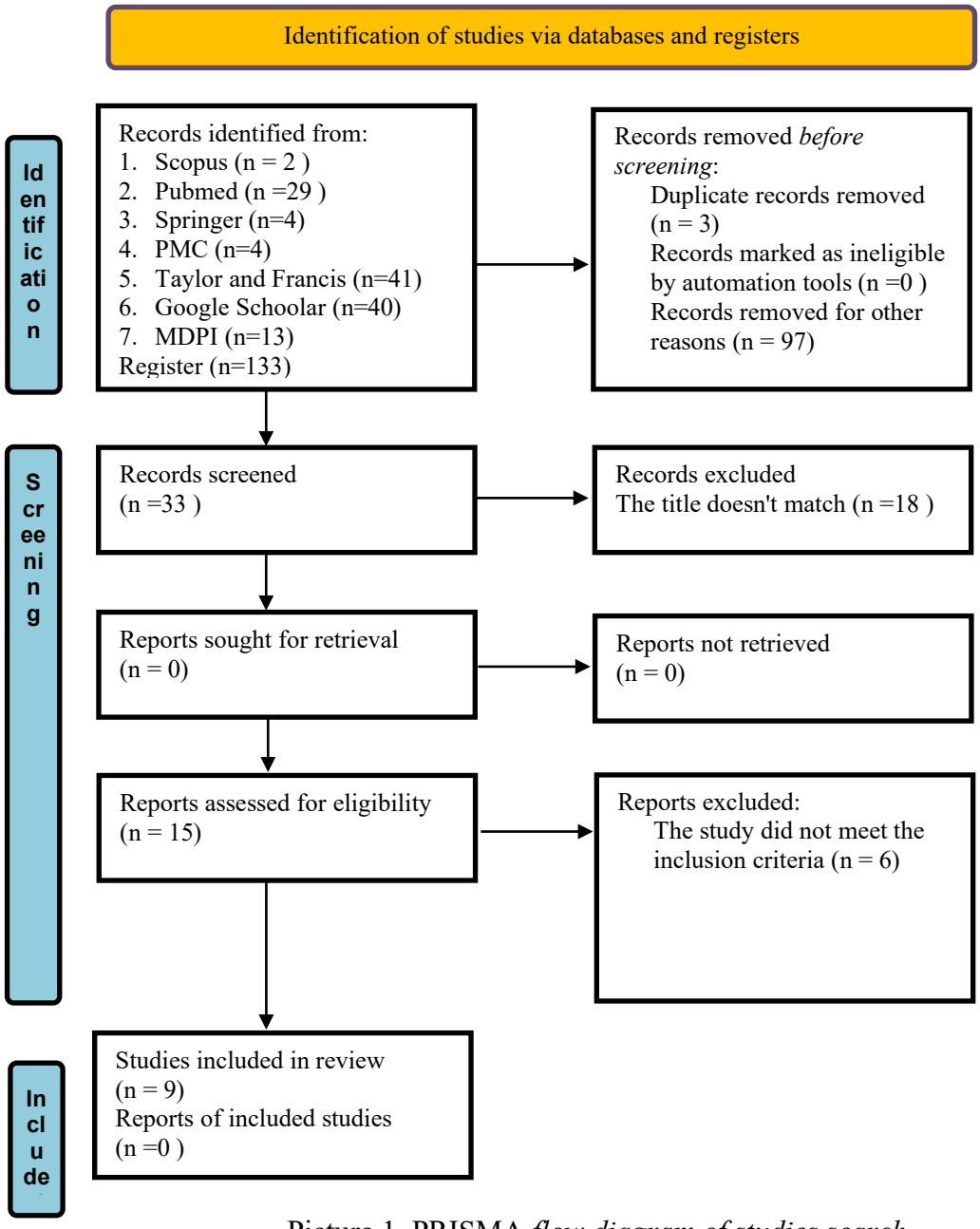
Based on this background, this systematic literature review (SLR) was conducted to integrate empirical evidence regarding the role of digital-based E-EWS systems in supporting the early detection of patient deterioration and nursing responses. By analyzing various studies related to study design, implementation processes, clinical outcomes, as well as supporting and inhibiting factors, this SLR aims to provide a comprehensive overview of the effectiveness of digital EWS interventions in modern clinical practice. The findings of this review are expected to serve as a basis for policy development, the preparation of standard operating procedures, and directions for future research in order to strengthen digital transformation and patient safety in hospitals.

METHOD

The method used in this article was a systematic literature review. The purpose of using this method was to identify the role of digital-based Electronic Early Warning Score (E-EWS) systems in the early detection of patient deterioration and nursing responses in hospitals. The articles used in this study were identified based on the following criteria: research articles published within a 10-year period (2015–2025); full-text research articles accessible to the authors; and articles published in English or Indonesian. The retrieved articles were selected based on their suitability with the PICOS criteria: Population (patients and nurses in hospitals), Intervention (digital-based Electronic Early Warning Score [E-EWS] or automated systems), Comparison (paper-based EWS or conditions

before E-EWS implementation), Outcomes ((1) accuracy of early detection of patient deterioration, (2) clinical response, (3) nurse compliance, and (4) patient safety), and Study design (quasi-experimental studies, randomized controlled trials [RCTs], before–after studies, cohort studies, or mixed-method implementation studies).

The literature search was conducted using the PubMed, PMC, Scopus, Google Scholar, Springer, and MDPI databases. Article searching was performed in November 2025. The search strategy used keywords such as " ("*Electronic Early Warning Score*" OR "E-EWS" OR "*digital early warning system*" OR "*automated early warning*") AND ("*patient deterioration*" OR "*clinical deterioration*" OR "*early detection*") AND ("*nursing response*" OR "*nurse adherence*" OR "*rapid response*" OR "*escalation*") AND (*inpatient* OR *hospital* OR *ward*). The retrieved articles were then analyzed by screening relevant titles, while irrelevant titles were excluded. Duplicate articles were also removed. The detailed process of article selection for analysis using the PRISMA framework is presented in Figure 1.



Picture 1. PRISMA *flow diagram of studies search*

RESULT

Table 1.
Literature Analysis Matrix

No	Author, Year, Country, Title	Research Design, Sample, and Study Area	Objective	Type of Digital EWS	Implementation Process	Role of EWS	Nursing Response	Study Results
1.	MA Rose, LA Hanna, SA Nur, and CM Johnson (2015), United States. Utilization of Electronic Modified Early Warning Score to Engage Rapid Response Team Early in Clinical Deterioration	Pre- and post-education intervention design. A total of 108 primary nurses. Area: three non-critical care units with 60 adult beds in the United States.	To improve patient-centered quality of care by engaging the Rapid Response Team (RRT) earlier in managing clinical deterioration through the use of eMEWS as a clinical decision support tool.	Electronic Modified Early Warning Score (eMEWS) as a Clinical Decision Support Tool and Capsule Vital Signs Now (CVSN).	This study evaluated the effectiveness of staff education regarding eMEWS by examining eMEWS scores and RRT/code blue data during two 90-day phases: pre-education intervention and post-education intervention.	Identified patient clinical deterioration through automatic summation of individual eMEWS element scores to generate a total eMEWS score. If the score reached a trigger score of 5 or higher or increased by 2 points, the system generated an alert and early RRT activation.	Staff education improved nurses' use of the tool as a clinical decision support system. Earlier activation of the Rapid Response Team (RRT). Improved rescue preparedness based on electronic MEWS scores.	There was a staff knowledge deficit before implementation. Education significantly increased the use of electronic MEWS (100%). Patient rescue strategies improved. RRT activation became earlier and more consistent.
2.	Pullinger et al. (2016/2017), United Kingdom. Implementing an Electronic Observation and Early Warning Score Chart in the Emergency Department: A Feasibility Study	Retrospective feasibility pre–post study. Sample: 3,219 participants before and 3,352 participants after implementation of the automated system. Area: tertiary referral and major trauma Emergency Department in Oxford, United Kingdom.	To evaluate the feasibility of implementing an electronic observation chart with automated Early Warning Score (EWS) calculation in an acute emergency department setting.	Mobile bedside entry and automatic EWS calculation.	Vital sign data were entered using mobile bedside devices connected to the network.	Improved accuracy of EWS documentation using electronic systems compared to paper-based systems. Evaluated the impact of EWS implementation on patient safety.	Increased observation of patients with high EWS scores.	EWS recording accuracy increased from 52.7% to 92.9%. Observation of patients with high EWS scores also increased.
3	Mestrom et al. (2019), Netherlands. Implementation of an Automated Early Warning Scoring System in a Surgical Ward: Practical Use and Effects on Patient Outcomes	Retrospective pre–post intervention study. Sample: Control group: 7,929 records from 320 patients; Intervention group: 8,781 records from 273 patients; Automated assessments: 3,418. Area: surgical high dependency unit in the Netherlands.	To evaluate the clinical use of automated Modified Early Warning Score (MEWS) systems in postoperative patients.	Automated Modified Early Warning Score (MEWS).	Implemen-tation included automatic vital sign recording, automated MEWS calculation, electronic score display, and alarms when scores increased. Conducted in two phases over 15 months: control phase and intervention phase.	Improved monitoring. More systematic early detection. Increased protocol compliance. Better documentation and data quality.	Increased completeness of MEWS assessment. Improved frequency and accuracy of vital sign monitoring. Greater compliance with EWS protocols. Increased nurse awareness of patient deterioration. Better documentation accuracy. Nurses were more prepared to perform clinical escalation.	Documentation completeness improved from 2.5% to 45.5% after implementation. The automated system reduced missed assessments, and nurses monitored high-MEWS patients more quickly. Compliance with EWS procedures improved from 1.1% to 25.4%. Process quality improved, although clinical outcomes (mortality, LOS, ICU readmission) did not significantly change.
4	Wu et al. (2021), Taiwan. Implementation of an Electronic National Early Warning System to Decrease Clinical	Prospective phased study (baseline, implementation, intensive). Sample: 39,161 hospitalized patients. Area: Taichung Veterans General Hospital	To evaluate the effectiveness of implementing an electronic NEWS (eNEWS) system to reduce	Digital National Early Warning Score (eNEWS) integrated with the	Development of an automated eNEWS system, integration into clinical workflow,	Automated monitoring of patient deterioration. Improved communication among healthcare	Increased clinical awareness. More consistent physiological monitoring. Faster and more structured inter-professional	eNEWS implementation was associated with a significant reduction in adverse events from 6.06% to 5.51%. Ward CPR

No	Author, Year, Country, Title	Research Design, Sample, and Study Area	Objective	Type of Digital EWS	Implementation Process	Role of EWS	Nursing Response	Study Results
	Deterioration in Hospitalized Patients at a Tertiary Medical Center	(TCVGH), a 1,500-bed tertiary medical center in central Taiwan.	unexpected clinical deterioration.	Health Information System (HIS) and Nurse Information System (NIS). The system automatically updated NEWS hourly to predict and reduce clinical deterioration.	hourly updates, use as a communi-cation tool among healthcare teams, monitoring of adverse events before and after imple-mentation, and real-time evaluation of clinical impact.	teams. Supported clinical decision-making. Improved patient safety and reduced adverse events. Real-time integration of vital sign data. Basis for future AI and big-data prediction systems.	communication Faster and more accurate clinical escalation. Increased protocol compliance. More effective prevention of adverse events. Adaptation of nursing workflows to digital systems.	events decreased from 0.52% to 0.34%. ICU transfers decreased from 3.63% to 3.49%. Nurse–physician communication improved. The system was highly effective when accompanied by training and audits.
5	Wahyudi et al. (2023), Indonesia. Development of a Web-Based National Early Warning Score 2 (NEWS2) Application for Initial Assessment of Patients with Acute Illness	Research and Development (R&D) study with functional testing. Sample: 4 patients (trial respondents). Area: Emergency Department of Muhammadiyah Hospital Palembang, Indonesia.	To develop a web-based NEWS2 application for the initial assessment of patients with acute illness.	Web-based National Early Warning Score 2 (NEWS2).	Development and testing of the NEWS2 web application on four patients in the Emergency Department of Muhammadiya h Hospital Palembang.	Improved effectiveness of early deterioration assessment in the Emergency Department.	Nursing response was not evaluated.	The web-based NEWS2 application was successfully tested on patients with acute illness in the Emergency Department. All respondents' levels of clinical deterioration were successfully assessed using the web-based NEWS2 application.
6	Wong et al. (2024), United Kingdom. Effect of Digital Early Warning Scores on Hospital Vital Sign Observation Protocol Adherence: Stepped-Wedge Evaluation	Two-armed stepped-wedge trial. Sample: 12,802 hospitalized patients divided into 1,084 control and 11,718 intervention groups. Area: four hospitals within the Oxford University Hospitals Foundation NHS Trust (OUHFT), United Kingdom.	To investigate whether implementation of a digital Early Warning Score system was associated with increased observation frequency among patients with abnormal vital signs, allowing faster clinical intervention.	SEND (System for Electronic Notification and Documen-tation).	SEND is a system in which healthcare staff manually enter vital sign observations into tablet PCs.	Improved early detection of patient deterioration. Improved accuracy and frequency of observations. Facilitated adherence to escalation protocols. Increased response speed and quality of nursing observations.	Improvement in nursing processes related to observation, documentation, and escalation.	Significant improvement in adherence to vital sign observation protocols among patients with high EWS scores. No increase in workload and no significant difference in time-to-next-observation (TTNO). Digital systems improved documentation consistency, and staff accepted the system positively.
7	Qaddumi et al. (2024), United Arab Emirates. The Effect of Implementation of the National Early Warning Scoring System 2 on the Outcomes of COVID-19 Hospitalized Patients	Quasi-experimental pre–post intervention study. Sample: 384 adult patients divided into control and study groups. Area: inpatient units of Martyr COVID-19 Military Medical Complex and Palestine Red Crescent Hospital.	To assess the effectiveness of NEWS2 in predicting clinical deterioration risk and outcomes among hospitalized COVID-19 patients.	National Early Warning Score (NEWS2) application.	Use of the NEWS2 application for monitoring clinical scores based on vital signs in COVID-19 patients.	NEWS2 as an early detection and risk prediction tool. Improved monitoring and clinical response. Positive impact on clinical outcomes. High predictive ability.	Improved observation and monitoring. More timely clinical escalation. More complete vital sign documentation. Increased awareness of deterioration. Improved inter-professional communicatio Sharper clinical judgment based on real-time data.	NEWS2 implementation was associated with improved outcomes in hospitalized COVID-19 patients, reduced length of stay, better prediction of deterioration, and improved continuous vital sign monitoring.
8	S. Ismail, Z. Wardah, A. Wibowo, S. Pranata, and S. Wahyuni (2025), Indonesia.	Cross-sectional analysis of E-EWS medical records using machine learning. Sample: vital sign data from	To apply machine learning algorithms to predict patient clinical status	E-EWS and machine learning.	Implementation involved collecting E-EWS and vital sign data, developing	More accurate prediction of patient clinical conditions. Faster early detection.	More frequent monitoring, rapid escalation, early intervention, coordination with physicians/RRT,	The study showed that E-EWS medical records integrated with machine learning could accurately

No	Author, Year, Country, Title	Research Design, Sample, and Study Area	Objective	Type of Digital EWS	Implementation Process	Role of EWS	Nursing Response	Study Results
	Predictive Analysis of Clinical Status Assessment of Critical Patients Using Electronic Early Warning System Records with Machine Learning	7,101 patients. Area: Emergency Department of Dr. Kanujoso Djatiwibowo Hospital, Balikpapan, East Kalimantan, Indonesia.	based on E-EWS records to improve early detection and support clinical decision-making in critical care settings.		deterioration prediction models, providing risk dashboards and alerts, and enabling nurses to perform validation, close monitoring, and rapid escalation.	Clinical decision support system for healthcare professionals. Real-time processing of E-EWS big data.	and more accurate documentation.	predict future patient conditions and outcomes using seven EWS parameters.
9	Santi Widianti Kuswara & Rycco Darmareja (2025), Indonesia. Implementation of Digitalized EWS and MEWS: Data Completeness and Escalation Suitability in the Alamanda Ward of Dr. Hasan Sadikin General Hospital in 2022	Pre-experimental one-group pre–post test design. Sample: 648 data entries before and after digitalization. Area: Alamanda inpatient ward, Dr. Hasan Sadikin General Hospital, Bandung, Indonesia.	To analyze differences in data entry completeness and escalation suitability before and after the digitalization of EWS and MEWS.	Digitalized Early Warning System (EWS) and Maternal Early Warning System (MEWS).	Completeness of data entry and escalation suitability were measured using an observation sheet based on the Guttman scale.	Improved data completeness. Automatic score generation. Display of escalation recommendation Increased protocol compliance. Easier quality audits.	More frequent and accurate monitoring. Faster clinical escalation. More complete and systematic documentation Faster decision-making. Increased clinical awareness. Improved inter-professional collaboration.	Digitalization of EWS and MEWS successfully improved data completeness and escalation suitability. This demonstrates that digitalization plays a major role in the early detection of patient deterioration, enhancement of nursing responses, and strengthening patient safety.

DISCUSSION

This systematic review included several studies evaluating the implementation and impact of digital-based Electronic Early Warning Score (E-EWS) systems across various clinical settings during the period 2015–2025. Overall, the synthesis results demonstrated five main findings: (1) improved accuracy and completeness of vital signs documentation, (2) faster and more consistent early detection of patient deterioration, (3) enhanced nursing responses and clinical escalation, (4) mixed findings regarding major clinical outcomes, and (5) the development of digital EWS systems.

Accuracy and Completeness of Vital Signs Documentation

Most studies reported that the use of digital E-EWS systems improved the accuracy of vital signs data entry compared to manual methods. Automated documentation and score calculation reduced calculation errors and variations in interpretation among nurses. Documentation completeness also improved because the system provided automatic reminders to perform observations according to the recommended intervals. The digitalization of EWS has been shown to improve accuracy and consistency in recording vital signs. Automatic score calculation reduces the risk of manual errors and enhances the reliability of patient monitoring. With alarms and visual risk indicators, healthcare professionals can detect changes in patient conditions more quickly, thereby increasing the opportunity to prevent clinical deterioration (David Chi-Wai, 2024; Ismail et al., 2025; Pullinger et al., 2016; Qaddumi, 2024; Rose et al., 2015).

The development of EWS protocols for bariatric patients based on continuous vital signs monitoring has also proven beneficial (Ede et al., 2022). Electronic Early Warning Score systems automatically calculate scores based on vital signs entered manually or retrieved directly from monitoring devices. This demonstrates that digitalization reduces manual calculation errors, simplifies the entry of vital sign parameters, produces more consistent data, and achieves higher accuracy compared to manual early warning systems (Ariani, 2025; Muralitharan et al., 2021; Subbe et al., 2017).

Improved Early Detection of Deterioration Risk

The implementation of digital E-EWS systems shortened the time required to identify patients at risk of clinical deterioration. Features such as automated alerts, real-time displays, and continuously updated vital sign data integration helped healthcare professionals recognize warning signs more quickly. Several studies demonstrated that E-EWS increased the number of patients identified at an early stage before clinical decompensation occurred (David Chi-Wai, 2024; Qaddumi, 2024; Rose et al., 2015; Wahyudi et al., 2023). These findings are supported by the study conducted by Noya, which showed that the implementation of digital NEWS improved the early detection of deteriorating patient conditions, reduced medical response times, and enhanced communication among healthcare teams (Noya et al., 2025). When a patient's risk score exceeds the predetermined threshold, the digital NEWS system automatically sends notifications, ensuring that healthcare personnel are immediately aware of conditions requiring urgent intervention (NICE, 2020).

More Consistent Nursing Responses and Clinical Escalation

The implementation of digital E-EWS systems contributed to improving the quality of nursing responses, including: (1) increased monitoring frequency according to risk scores, (2) more effective interprofessional communication, (3) faster clinical escalation, and (4) more timely activation of Rapid Response Teams (RRT). Digital systems integrated with Electronic Medical Records (EMR) enabled automatic dissemination of risk information to medical teams, thereby accelerating clinical decision-making processes. Nursing responses are highly dependent on the speed and accuracy of actions taken based on risk scores.

Digital systems facilitate: (1) improved quality of communication among healthcare professionals, (2) better clinical coordination, and (3) more timely escalation, which ultimately helps prevent "failure to rescue." This demonstrates that E-EWS functions not only as a monitoring tool but also as a clinical decision support system (Id et al., 2019; Rose et al., 2015; Santi Widianti Kuswara, 2025; Wu et al., 2021). The implementation of digital NEWS has been shown to reduce medical response times and improve communication among healthcare teams (Noya et al., 2025).

The accuracy of clinical escalation and rapid response has a significant impact on the quality of maternal care, patient safety, and hospital service quality (Santi Widianti Kuswara, 2025). This maternal monitoring system was developed to provide integrated information for physicians regarding labor and delivery processes while also identifying high-risk patients or those showing changes in clinical condition (Klumpner et al., 2018). Accurate escalation and rapid, appropriate clinical responses play an important role in improving the quality of maternal healthcare services and patient safety. Digital integration in healthcare services, including the use of early warning systems, can improve service quality and provide more reliable data to support clinical decision-making. However, the sustainability of these benefits still depends on continuous system improvement and refinement, as well as regular staff training (Ebenso, 2022).

Effectiveness on Clinical Outcomes Remains Variable

Although improvements were observed in clinical processes, the impact of E-EWS on major clinical outcomes such as mortality, unplanned ICU admissions, and cardiac arrest showed inconsistent findings. Several studies reported reductions in critical events following the implementation of digital systems, while other studies found no significant differences. These variations suggest that other external factors also influence patient outcomes. The inconsistency in findings related to mortality or unplanned ICU admissions indicates that E-EWS is not the sole factor affecting clinical outcomes. Organizational factors, such as staff availability, patient safety culture, and the readiness of information technology systems, also determine how effectively the system can be implemented. In hospitals where clinical escalation processes are already well established, the addition of digital systems may not demonstrate significant differences (Ismail et al., 2025; Qaddumi, 2024; Wu et al., 2021).

The effectiveness of digital E-EWS depends on the quality of implementation, including: (1) user training, (2) integration with Electronic Medical Records (EMR), (3) clarity of clinical escalation pathways, (4) management support, and (5) continuous monitoring. Implementation without comprehensive preparation may lead to alarm fatigue, miscommunication, or suboptimal utilization of real-time data. Research conducted by Endang Sudjiati concluded that the use of information technology improved nurses' knowledge and skills in nursing practice. The use of Early Warning Scoring System (EWSS) devices did not reduce the quality of healthcare services provided. Furthermore, the implementation of EWSS information technology reduced nurses' workload, decreased mortality rates, and provided benefits for hospital organizations (Endang Sudjiati, 2019).

Development of Digital EWS

EWS systems have been widely developed and implemented in developed countries to identify clinical deterioration as early as possible. Previous studies have shown that prehospital NEWS2 scores are easy to obtain and represent a reliable tool, making them an ideal system to support the initial assessment of high-risk patients and to determine triage levels effectively and efficiently (Martín-Rodríguez et al., 2019).

Machine learning can accurately predict future patient conditions and outcomes using seven EWS parameters (Ismail et al., 2025). Machine learning approaches can improve the accuracy and quality of triage predictions in assessing patients' clinical conditions in the Emergency Department (ED). Several studies have demonstrated that this method provides superior predictions compared to conventional triage systems or EWS alone because it allows the inclusion of variables beyond vital sign parameters, such as blood glucose levels. The addition of these variables has been proven to improve the accuracy of mortality risk prediction (Pirneskoski et al., 2020).

Nurses use E-EWS records during patient assessment to help identify physiological abnormalities before clinical deterioration occurs during cardiac arrest events. Therefore, the use of machine learning models may help reduce risk by improving the detection of patients who are likely to require ICU admission (Howell et al., 2018). Previous studies have shown that vital sign data from EWS scores can be efficiently processed using machine learning algorithms to predict the risk of in-hospital cardiac arrest and the likelihood of ICU admission due to unanticipated critical conditions (Cho et al., 2020).

Wahyudi developed a NEWS2-based web application. The NEWS2-based web application uses vital sign parameters and displays score alerts/triggers with an automatic NEWS2 calculation instrument. NEWS2 studies in Indonesia demonstrated that the system functioned well and reduced human error in score calculation (Wahyudi et al., 2023). Digital learning-based early warning systems can achieve higher accuracy than manual early warning systems (Muralitharan et al., 2021). The findings of this systematic literature review indicate that digital transformation through E-EWS can support patient safety when accompanied by strong healthcare governance**.**

CONCLUSION

This Systematic Literature Review demonstrates that digital-based Electronic Early Warning Score (E-EWS) systems have substantial potential to enhance the early identification of patient deterioration through more accurate, consistent, and real-time monitoring of vital signs. The implementation of digital EWS systems has been associated with faster clinical escalation processes and improved accuracy of clinical responses, particularly in nursing practices related to patient monitoring, interprofessional communication, and early intervention.

The majority of studies reviewed indicated that E-EWS implementation contributes positively to patient safety by minimizing delays in the recognition of critical conditions and improving coordination among healthcare professionals. Nevertheless, the heterogeneity of study designs and

variations in implementation standards across healthcare settings limit the generalizability of the findings. Further large-scale and standardized studies are therefore required to strengthen the evidence regarding the effectiveness of digital E-EWS systems in improving clinical outcomes and healthcare quality.

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