

# Beyond Monitoring: Wearable Technology as a Tool for Early Recognition of Clinical Deterioration in Emergency Care

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## Abstract

Emergency units deal with major challenges like too many patients, not enough healthcare workers, and a high chance of missing signs of worsening health. Using traditional methods to check vital signs only at certain times can miss important changes, which is why a new, tech-based solution is needed. This article looks at the latest research on how wearable technology can help detect when a patient's condition is getting worse early on in emergency care. The study used a literature review approach, searching through databases like PubMed, EBSCO, ProQuest, Google Scholar, and MDPI. The search used the terms "wearable technology," "emergency care," "clinical deterioration," and "vital signs monitoring." Out of 44 articles found between 2017 and 2025, 10 were chosen based on full-text review and how closely they matched the topic. The research shows that wearable devices can monitor important body functions like heart rate, breathing rate, oxygen levels, temperature, and blood pressure in real time. These devices can give early warnings about a patient's condition worsening and help make better, data-based decisions in care. The devices are also portable, comfortable, and easy to use, and they don't stop patients from moving around. Using wearables has been linked to better patient safety because they help act faster, reduce the risk of not saving a patient, and may lower death rates. However, some issues remain, such as the accuracy of certain sensors, problems combining the technology with existing systems, and how well healthcare workers accept using these devices. Overall, wearable technology shows a lot of promise in helping emergency nursing by catching early signs of health problems and improving patient safety, but more clinical testing and better integration with existing systems are still needed.

**Keywords:** *Early Detection, Emergency Care, Patient Safety, Vital Signs, Wearable Technology.*

## I. BACKGROUND

Emergency services are currently facing increased operational and clinical pressures globally, marked by a rise in visit volumes, overcrowding in treatment rooms, and nursing staff shortages that directly risk prolonging wait times, delaying the detection of patient deterioration, and increasing adverse events and mortality. For example, visits to emergency departments in the United States

remain very high ( $\pm 140$  million visits in 2024), and international reports indicate that overcrowding in EDs exists in almost all respondent countries, with real consequences for patient quality and safety. This pressure is exacerbated by nursing shortages and high burnout rates, placing an increased burden on nurses in the emergency department to monitor patients and detect early clinical deterioration (Joshi et al., 2025).

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An emergency condition is a clinical situation characterized by rapid and unexpected changes in a patient's physiological status, making early detection of clinical deterioration critical to prevent serious complications and death. Conventionally, monitoring of a patient's vital signs is performed intermittently by healthcare personnel, which can potentially lead to delays in recognizing early signs of deterioration (Downey et al., 2018).

In fast-paced and busy practice settings such as the ED, early detection of physiological changes (e.g., decreased oxygen saturation, increased respiratory rate, tachycardia, or hypotension) is critical to prevent failure to rescue patients. However, traditional monitoring systems that rely on periodic measurements by staff risk missing critical fluctuations between checks. This is where wearable sensor technology, which can be attached to patients for continuous monitoring of vital signs (HR, RR, SpO<sub>2</sub>, temperature, blood pressure), offers a promising solution: with real-time data flow and integration into early warning scores or digital notification systems, wearables have the potential to detect clinical deterioration faster, support clinical prioritization, and reduce the burden of manual monitoring on nurses (Michard & Saugel, 2024).

Advances in digital technology, particularly wearable devices, have created new opportunities for continuous patient monitoring. These devices are capable of recording key physiological parameters such as heart rate, respiratory rate, temperature, and oxygen saturation, and transmitting data in real time for analysis by an early warning system (Ismail et al., 2025). Thus, wearables can increase sensitivity in detecting clinical deterioration more quickly than conventional monitoring methods.

Several studies show that the use of wearable sensors in emergency rooms and acute care wards can help healthcare professionals identify patients at risk of deterioration earlier, improve clinical response, and contribute to patient safety (Itelman et al., 2022a). In addition, the early clinical exposure program through this technology also facilitates data integration into electronic medical record systems and supports evidence-based clinical decision making (Reichl et al., 2024).

However, the implementation of wearables in emergency settings still faces challenges, including the validity and reliability of sensors in critically ill patients, integration with hospital technology infrastructure, and acceptance by healthcare professionals in practice (Joshi et al., 2025). Therefore, a literature review is needed to examine the latest evidence regarding the role of wearable technology in the early detection of clinical deterioration in emergency patients, so as to provide a comprehensive overview of its potential, limitations, and future development directions.

This is the background for the purpose of writing this literature review to analyze the Role of Wearable

Technology in Early Detection of Clinical Status Decline in Emergency Patients: A Literature Review.

## II. METHODE

The method used in this paper is a literature review, which involves searching for both international and national literature using the Google Scholar, EBSCO, Pubmed, and Proquest databases. The author created a list of search terms for each electronic database to refine the terms, such as:

- *Wearable technology OR wearable device OR wearable sensor OR biosensor*
- *Emergency care OR emergency department OR critical care OR acute care*
- *Clinical deterioration OR early detection OR early warning OR clinical status decline*
- *Patient monitoring OR vital signs monitoring OR remote monitoring*

In the initial search phase, 44 journal articles from 2017 to 2025 were obtained using the keywords described by the author. The databases included EBSCO with 33 articles, PubMed with 20 articles, ProQuest with 20 articles, MDPI with 2 articles, and Scholar with 2 articles. The author reviewed and eliminated 25 journal articles by reading the titles and then the abstracts of those articles. Of these, only 10 articles were considered relevant to the full-text criteria and within the literature limitations set by the author.

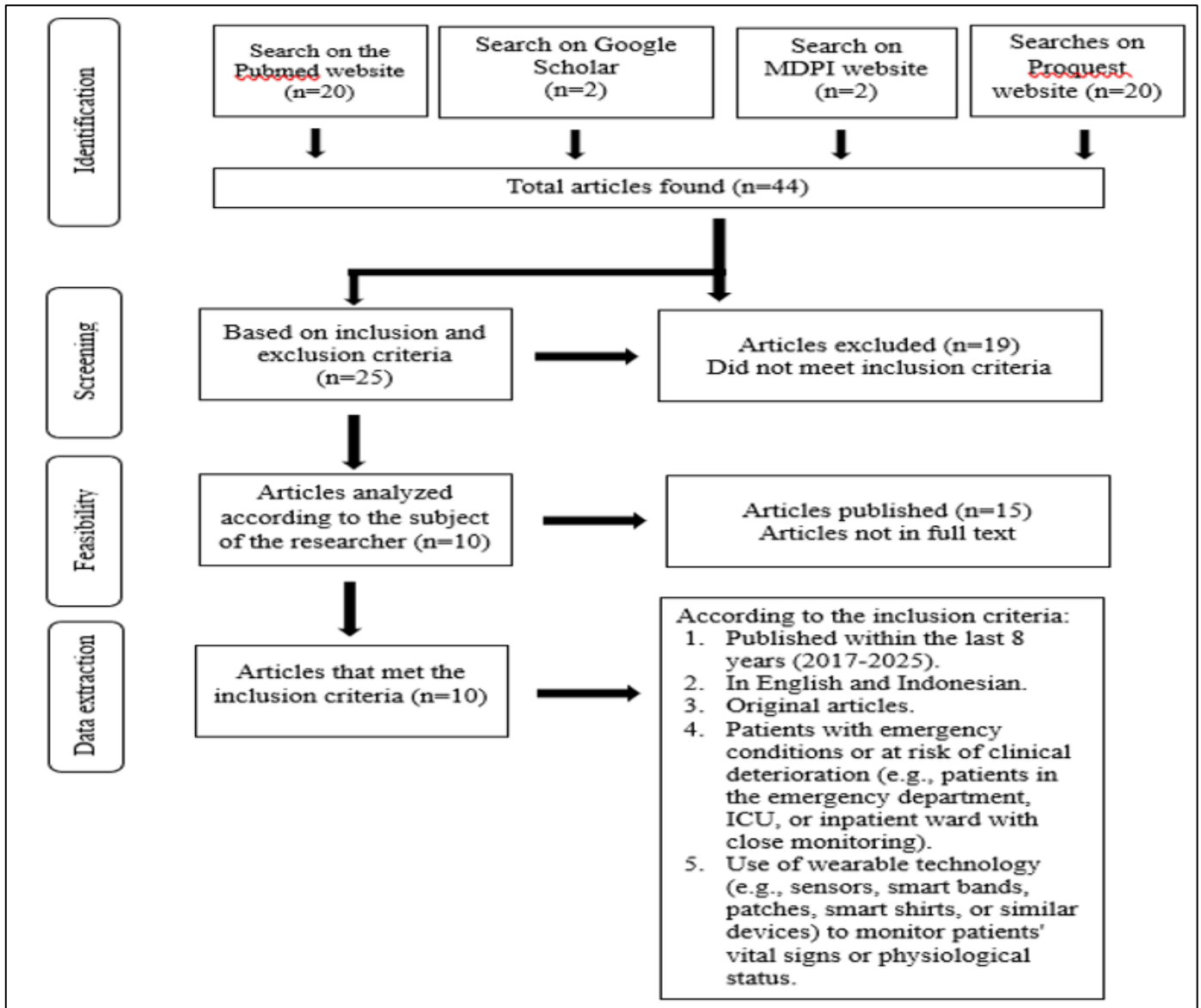


Fig 1 Prisma Literature Review

### III. RESULT

Table 1 Result

No.	Researcher (Year)	Research Title	Research Method and Objective	Sample Criteria and Intervention	Results
1	(Reed et al., 2018)	Detection of physiological deterioration by the SNAP40 wearable device compared to standard monitoring devices in the emergency department	<b>Method:</b> Data collected using Behavior AI Recovery™ app connected with smartwatches (Empatica E4, Garmin Vivomove 3, Garmin Vivoactive 3/4, Fitbit Charge 3). Continuous 28-day monitoring of HR, HRV, stress, steps, and self-report every 8 hours. Analysis: correlation-regression, Poincaré plot HRV, Fourier Transform, Baevsky stress index. <b>Objective:</b> Evaluate smartwatch + AI in early detection of cardiovascular disorders and stress, including predicting opioid craving.	<b>Sample:</b> 21 initial smartwatch users, 12 final with complete data. <b>Intervention:</b> Continuous monitoring with smartwatch + AI, no direct medical intervention.	Significant correlation between HR and stress ( $r=0.83-0.91, p<0.05$ ). HRV plots revealed rhythm risks. AI predicted opioid craving. <b>Conclusion:</b> smartwatch + AI effective for early cardiovascular detection; larger studies recommended.

No.	Researcher (Year)	Research Title	Research Method and Objective	Sample Criteria and Intervention	Results
2	(Joshi et al., 2025)	Performance of Continuous Digital Monitoring of Vital Signs with a Wearable Sensor in Acute Hospital Settings	<b>Method:</b> Prospective cohort in London hospitals (2018–2019) using Sensium sensor. Compared with nurse observations using Bland–Altman, ICC, Kappa. <b>Objective:</b> Evaluate reliability and best alert window.	<b>Sample:</b> 1398 screened, 500 recruited ( $\geq 18$ years, acute wards, $\geq 24$ h stay). <b>Intervention:</b> Sensium sensor on chest, recording HR, RR, temp every 2 min; nurses still observed every 4–6h.	27,397 data points. HR reliable (ICC=0.66, $r=0.86$ ). RR poor accuracy (ICC=0.20). Temp fair (ICC=0.30). Kappa: HR 97%, RR 82%, Temp 60%. <b>Conclusion:</b> Reliable for HR, fair for temp, poor for RR. 10-min window best for alerts.
3	(Nesvit et al., 2025)	Early Detection of Patient Deterioration from Real-Time Wearable Monitoring System	<b>Method:</b> TARL (Transition-Aware Representation Learning) on HR data from wearables. Shapelet-transition graph, attention embeddings. <b>Objective:</b> Detect ICU deterioration up to 6h before diagnosis with explainable AI.	<b>Sample:</b> 58 ICU patients, Taiwan. HR series every 1 min. APACHE II as ground truth. <b>Intervention:</b> Continuous HR monitoring analyzed with TARL AI.	TARL accuracy 0.61, recall 0.92, F1 0.74. Detected 6h earlier (earliness 0.79). Robust with 30% missing data. <b>Conclusion:</b> TARL effective, robust, explainable for ICU deterioration detection.
4	(Wahyudi & Ramadhani, 2025)	Effectiveness of Wearable Technology in Monitoring Post-Myocardial Infarction Patients	<b>Method:</b> Comparative quantitative study. Manual vs smartwatch monitoring. Analysis: t-test, Mann Whitney. <b>Objective:</b> Evaluate wearable effectiveness post-MI.	<b>Sample:</b> 25 post-MI patients in Muhammadiyah Hospital Palembang. Criteria: cooperative, communicative, follow-up program. <b>Intervention:</b> Manual vs smartwatch monitoring (HR, temp, BP, SpO <sub>2</sub> , random blood sugar).	Significant difference in blood sugar ( $p=0.001$ ) → wearable inaccurate for glucose. <b>Conclusion:</b> Effective for HR, temp, BP, SpO <sub>2</sub> but not for glucose.
5	(Reichl et al., 2024)	Pilot Study of a Wearable Device for Continuous Monitoring and Automated Early Warning Score in Hospitalized Patients	<b>Method:</b> Pilot observational using Healthdot wearable every 5 min. Compared auto-EWS vs manual nurse EWS. <b>Objective:</b> Assess feasibility and accuracy.	<b>Sample:</b> 20 adult inpatients, Netherlands. Inclusion: $\geq 18$ years, $\geq 24$ h stay, non-ICU. <b>Intervention:</b> Healthdot monitoring HR, RR, activity; auto-EWS generated.	91% recording success. Good HR accuracy, RR variable. <b>Conclusion:</b> Feasible for inpatient monitoring; RR needs improvement.
6	(Ramadhani Amran et al., 2025)	The Role of Remote Patient Monitoring via Wearable Devices in Emergency and Acute Care Settings	<b>Method:</b> Narrative review (2017–2023) of wearables in ED/acute care. <b>Objective:</b> Explore effectiveness, benefits, limitations.	<b>Sample:</b> Research articles, clinical trial reports. <b>Intervention:</b> Review of ECG patches, HR/SpO <sub>2</sub> monitors, remote monitoring systems.	<b>Benefits:</b> Faster detection vs manual, improved safety, reduced workload. <b>Challenges:</b> Accuracy, false alarms, system integration, privacy. <b>Conclusion:</b> Promising, needs large-scale studies.
7	(Ismail et al., 2025)	Predictive Analysis of Clinical Status of Critical Patients Using E-EWS with	<b>Method:</b> Cross-sectional. Random Forest on E-EWS. <b>Objective:</b> Predict clinical status and deterioration.	<b>Sample:</b> 206 patients, Balikpapan hospital ED (Aug–Oct 2023). $\geq 18$ years, triage 1–2, $\geq 72$ h stay. <b>Intervention:</b> Android/web E-EWS	Accuracy: 82.26%. 48h: 76.19%. 72h: 71.43%. Outcome prediction: 97.62%. <b>Conclusion:</b> ML-based E-EWS more accurate than manual.

No.	Researcher (Year)	Research Title	Research Method and Objective	Sample Criteria and Intervention	Results
		Machine Learning		monitored, ML analysis.	
8		Smartwatch ECG and AI in Detecting Acute Coronary Syndrome Compared to 12-lead ECG	<b>Method:</b> Ad hoc analysis. Compared 12-lead vs 9-lead smartwatch ECG analyzed by AI. <b>Objective:</b> Assess AI+smartwatch in ACS.	<b>Sample:</b> 71 subjects: 44 ACS with occlusion, 12 ACS without, 15 healthy. Italy (2019–2020). <b>Intervention:</b> Sequential 12-lead + smartwatch ECG, analyzed by AI.	High correlation ( $\rho > 0.88$ ). AUROC nearly identical (qACS 0.987 vs 0.991). AI matched/exceeded cardiologists. <b>Conclusion:</b> AI+smartwatch ECG comparable to standard, useful out-of-hospital.
9	(A. Choi et al., 2022)	Advantage of Vital Sign Monitoring Using Wireless Wearable Device for Predicting Septic Shock in Febrile ED Patients: ML Analysis	<b>Method:</b> Retrospective with Hicardi wearable (HR, RR, temp, activity) vs manual. CNN & LSTM used. <b>Objective:</b> Predict septic shock in febrile ED patients.	<b>Sample:</b> 468 febrile patients ( $\geq 18$ years, $> 38^\circ\text{C}$ ). <b>Intervention:</b> Hicardi patch continuous HR & RR monitoring every 5 min up to 24h.	Wearable HR & RR matched manual. Septic shock AUROC: wearable 0.861 vs manual 0.853. Detected 5.5–9h earlier. <b>Conclusion:</b> Wearables superior for early septic shock detection.
10	(Miller et al., 2021)	Deployment of Wearable Biosensor System in the Emergency Department: A Technical Feasibility Study	<b>Method:</b> Technical feasibility study. <b>Objective:</b> Assess feasibility and patient acceptance of biosensors in ED Observation Unit.	<b>Sample:</b> 44 adult ED patients. <b>Intervention:</b> Disposable chest biosensor (HR, RR, activity, posture) + patient questionnaire.	Data transmitted in 93.2% cases. Patients reported comfort (93.2%) and reuse willingness (90.9%). No serious side effects. <b>Conclusion:</b> Biosensors feasible and acceptable in ED and home-care.

#### IV. DISCUSSION

From the literature that has been collected, the author attempts to find several discussions related to Wearable Technology in Early Detection of Clinical Status Decline in Emergency Patients. Here are some of the discussions that the author has found:

##### ➤ Real-Time Physiological Monitoring

Wearable technology in emergency services lies in its ability to perform real-time and continuous physiological monitoring. Using wireless sensors, smartwatches, and biosensor patches, healthcare professionals can continuously monitor vital parameters such as heart rate, respiratory rate, oxygen saturation, body temperature, and blood pressure. This type of monitoring is very important, because conventional methods that are performed intermittently risk missing changes in clinical status that occur between examination intervals.

Real-time monitoring not only speeds up the detection of changes in clinical status, but also supports healthcare workers in reducing the burden of manual observation. In busy emergency room and ICU situations, nurses often face time constraints when it comes to taking vital signs measurements on a regular basis. The presence of wearables enables a continuous flow of data that is

directly connected to the monitoring system, allowing healthcare workers to focus on more urgent clinical interventions.

##### ➤ Early Detection of Clinical Deterioration

Wearable technology has also been proven effective in the early detection of clinical deterioration. A common finding across various literature is the ability of these devices to provide automatic alerts when there is a deviation from normal physiological values. A study by Choi et al. (2022) shows that the use of the Hicardi wearable patch in patients with fever in the emergency department can predict the onset of septic shock several hours earlier than manual methods. In fact, the device can identify the risk of sepsis up to 9 hours earlier, a crucial achievement in accelerating the administration of therapy.

Similar findings were reported by Nesvit et al. (2025) who developed the Transition-Aware Representation Learning (TARL) algorithm. This algorithm is capable of analyzing data from wearable devices and detecting a decline in the clinical condition of ICU patients up to six hours before a clinical diagnosis is made. This shows that wearables, when combined with artificial intelligence, not only serve as monitoring tools, but also as early prediction systems (predictive analytics).

### ➤ *Clinical Decision Support*

Wearable technology can serve as clinical decision support. Data collected in real time is not only displayed in numerical form, but can also be processed into an early warning score (EWS) or even processed with machine learning algorithms to provide predictions of a patient's clinical status. Reichl et al. (2024) found that the Healthdot wearable device was able to generate automatic EWS scores comparable to manual scores calculated by nurses. This makes it easier for healthcare workers to stratify patient risk, especially in acute care wards with large numbers of patients. Ismail et al. (2025) adding that the use of machine learning-based electronic early warning scores (E-EWS) can predict the outcome of critical patients with an accuracy of up to 97.6%. These findings reinforce the role of wearables as an integral part of data-driven clinical decision support systems.

### ➤ *Mobility and Ease of Use*

Patient comfort and mobility are also important points discussed in the literature. Almost all of the journals reviewed agree that wearables have advantages in terms of portability and ease of use. Miller et al. (2021) reported that the majority of patients in the emergency room observation unit felt comfortable using wireless biosensors and were willing to wear the devices again if necessary. This shows that wearables do not interfere with patient activities, including when patients need to be transferred from one unit to another or when patients need to perform limited mobilization. From the healthcare provider's perspective, wearables are also relatively easy to install and the data obtained can be directly connected to the hospital server. This is in contrast to wired monitoring, which restricts patient movement, increases the risk of sensor dislocation, and requires extra manpower for installation.

### ➤ *Improved Patient Safety*

With real-time monitoring, early detection of deterioration, and data integration into clinical systems, wearables can reduce the risk of failure to rescue—that is, failure to detect signs of deterioration, leading to delayed intervention. Itelman et al. (2022b) emphasize that wearables can accelerate clinical response in the emergency department, reduce adverse events, and potentially lower mortality rates. Choi et al. (2025) It even shows that ECG smartwatches combined with artificial intelligence have diagnostic performance comparable to conventional ECGs in detecting acute coronary syndrome (ACS). This opens up opportunities for wearables to be used not only for routine monitoring, but also for early diagnosis of life-threatening cardiovascular conditions.

## V. CONCLUSION

Based on a review of the literature, wearable technology has been proven to play an important role in the early detection of clinical deterioration in emergency patients through real-time physiological monitoring, early warning of vital sign deviations, support for clinical decision-making, and ease of use that does not restrict patient mobility. These advantages contribute significantly

to improving patient safety by reducing delays in intervention and lowering the risk of failure to rescue. However, challenges related to sensor accuracy, hospital system integration, and healthcare worker acceptance still need to be addressed through further development and large-scale clinical validation. Therefore, healthcare professionals are expected to optimize the use of wearable devices in clinical practice, particularly in emergency departments and critical care units, while considering technological limitations and conducting ongoing evaluations of their effectiveness and safety.

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