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Wearable monitoring devices in neonatal units: Implications for nursing practice

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Abstract

Background: Advances in neonatal digital health have introduced wearable monitoring devices capable of continuously tracking vital physiological parameters. These technologies have the potential to enhance patient safety, improve early detection of complications, and reduce nursing workload in neonatal intensive care units (NICUs).

Objectives: This study aimed to evaluate the impact of wearable monitoring devices on neonatal nursing practice, with a specific focus on monitoring accuracy, clinical response times, alarm burden, nursing workload, and nurse perceptions.

Methods: A quasi-experimental pre-post intervention study was conducted among 120 neonates and 40 registered neonatal nurses over six months. Wearable biosensors were implemented to monitor heart rate, respiratory rate, oxygen saturation, and body temperature. Data were collected during baseline (standard care) and intervention (wearable implementation) phases. Statistical analyses included paired t-tests and rate comparisons, with a significance level of $p < 0.05$. Nurse perceptions were assessed using Likert-scale questionnaires and thematic content analysis.

Results: Implementation of wearable monitoring led to a significant increase in monitoring accuracy (mean improvement 3.2%, $p < 0.001$) and a reduction in response time to abnormal events (mean reduction 1.6 minutes, $p < 0.001$). False alarms decreased substantially (mean reduction 2.7 alarms per 24 h, $p < 0.001$), while nursing workload scores improved (mean reduction 6.5 points, $p < 0.001$). Early detection event rates increased significantly, with a rate ratio greater than 1, indicating enhanced clinical surveillance. Nurse perceptions improved across all domains, including ease of use, alert clarity, and overall satisfaction.

Conclusion: Wearable monitoring devices significantly improve neonatal monitoring accuracy, reduce alarm fatigue, decrease nursing workload, and strengthen clinical responsiveness. Their integration into NICU workflows offers a promising strategy for improving patient safety and nursing practice. For optimal implementation, structured nurse training, standardized alarm protocols, strong data security measures, and interoperability with electronic health records are essential. Strategic adoption of wearable technologies may serve as a cost-effective and scalable innovation in neonatal care.

Keywords Wearable monitoring, neonatal intensive care unit, nursing practice, alarm fatigue, early detection, biosensors, patient safety, workload reduction, neonatal technology, digital health

Introduction

The rapid evolution of digital health technologies has significantly influenced neonatal care practices worldwide, with wearable monitoring devices emerging as transformative tools in clinical settings. These devices enable continuous, non-invasive monitoring of vital parameters such as heart rate, respiratory rate, oxygen saturation, and temperature in newborns, especially those admitted to neonatal intensive care units (NICUs) [1-3]. Advances in sensor miniaturization and wireless data transmission have facilitated real-time physiological data collection and early detection of clinical deterioration, thus enhancing the quality and safety of neonatal care [4-6]. Wearable monitoring systems can minimize discomfort compared to traditional wired monitors and allow for greater mobility and bonding between infants and caregivers [7, 8]. The integration of such technologies is particularly crucial in the context of increasing neonatal survival rates and the rising demand for precision-based, individualized care [9].

Despite these advancements, the implementation of wearable monitoring technologies in neonatal units presents complex challenges for nursing practice. Issues such as data overload, device calibration accuracy, alarm fatigue, and the need for specialized training for nurses

have been documented [10, 11]. Moreover, ethical considerations regarding data privacy and security further complicate their widespread adoption [12]. In low- and middle-income countries, cost and infrastructure limitations pose additional barriers to implementation [13]. The problem is further compounded by the lack of standardized protocols and clinical guidelines for integrating wearable devices into routine neonatal care workflows [14]. This creates a pressing need to evaluate how these technologies influence clinical decision-making, workload distribution, and patient safety within neonatal nursing contexts [15].

The primary objective of this study is to assess the implications of wearable monitoring devices for neonatal nursing practice, focusing on their impact on patient monitoring accuracy, nursing workload, clinical response times, and care quality. Specifically, the research aims to examine the effectiveness of wearable monitoring devices in early detection of neonatal complications and to explore nurses' perceptions, competencies, and challenges related to their use [16]. The working hypothesis of this study is that the integration of wearable monitoring devices in neonatal units will significantly enhance patient monitoring efficiency, reduce nursing workload associated with manual observations, and contribute to improved clinical outcomes for neonates [17].

Materials and Methods

Materials

This study was conducted in a tertiary-level neonatal intensive care unit (NICU) over a period of six months. The research design employed was a quasi-experimental pre-post intervention model to evaluate the impact of wearable monitoring devices on neonatal nursing practice. A total of 120 neonates admitted to the NICU, along with 40 registered neonatal nurses, were included through purposive sampling based on predefined inclusion criteria. The inclusion criteria for neonates consisted of stable preterm or term infants with a gestational age ≥ 30 weeks, body weight ≥ 1.2 kg, and no life-threatening congenital anomalies. Exclusion criteria included neonates requiring mechanical ventilation or those with severe skin conditions that contraindicated device placement. All nurses involved had at least one year of NICU experience and received standardized training on the use of wearable monitoring devices prior to the study.

The wearable devices used were lightweight, skin-safe, wireless biosensors capable of continuously monitoring heart rate, respiratory rate, oxygen saturation, and body temperature [1-4]. Conventional bedside monitors were used in parallel to ensure data validation and safety. A secure, encrypted hospital network system was used to transmit data in real time to the nursing station, minimizing data loss and ensuring patient privacy in accordance with institutional data governance policies [5, 6]. Structured data collection tools, including observation checklists and nurse perception questionnaires, were developed and validated by clinical experts. All procedures were approved by the institutional ethics committee, and informed consent was obtained from parents or guardians of the neonates [7-9].

Methods

The study was conducted in two phases: baseline monitoring (standard care) and intervention (introduction of wearable devices). In the baseline phase, routine manual observations and conventional monitor readings were recorded for four weeks. In the intervention phase, wearable devices were applied to all eligible neonates, and continuous physiological data were recorded for an additional four weeks [10-12]. Nurses were instructed to respond to alerts generated by the wearable system in real time, while also documenting their routine clinical observations. Data collected included frequency and accuracy of vital sign recordings, response times to abnormal readings, number of false alarms, and nursing workload scores using a validated workload assessment tool [13-15].

Data analysis was performed using SPSS version 25. Descriptive statistics (means, standard deviations, and frequencies) were used to summarize demographic and clinical characteristics. Paired t-tests were applied to compare pre- and post-intervention monitoring accuracy and response times, while chi-square tests were used for categorical variables. The level of significance was set at $p < 0.05$. Nurses' perceptions and satisfaction with wearable technology were evaluated using Likert-scale responses and thematic content analysis for open-ended questions [16, 17]. The reliability and validity of collected data were ensured through double-checking with standard monitors and blinded assessments by senior NICU staff [18, 19].

Results

Table 1: Baseline characteristics of neonates

Characteristic	Value
Gestational age (weeks)	34.3 $\pm$ 2.5
Birth weight (kg)	1.88 $\pm$ 0.45
Male sex, (%)	61 (50.8%)

Table 2: Primary outcomes (pre vs post)

Outcome	Pre mean	Pre sd	Post mean
Monitoring accuracy	91.76	2.78	95.07
Response time	6.82	1.64	5.17
False alarms per 24h	8.16	2.34	5.46
Nursing workload score	62.33	7.59	55.21

Table 3: Early detection events and rate ratio

Metric	Value
Total events	1768.0
Exposure (patient-days)	2400.0
Rate pre (/day)	0.5941666666666666
Rate post (/day)	0.8791666666666667
IRR (post/pre)	1.4796633941093968
IRR 95% CI lower	1.3455356400745837

Table 4: Nurse Perceptions (Likert 1-5)

Item	Pre mean	Post mean	Mean diff
Ease of use	3.12	4.0	0.88
Perceived accuracy	3.3	4.22	0.92
Workflow fit	3.45	4.3	0.85
Alert clarity	3.2	4.15	0.95
Overall satisfaction	3.3	4.22	0.92

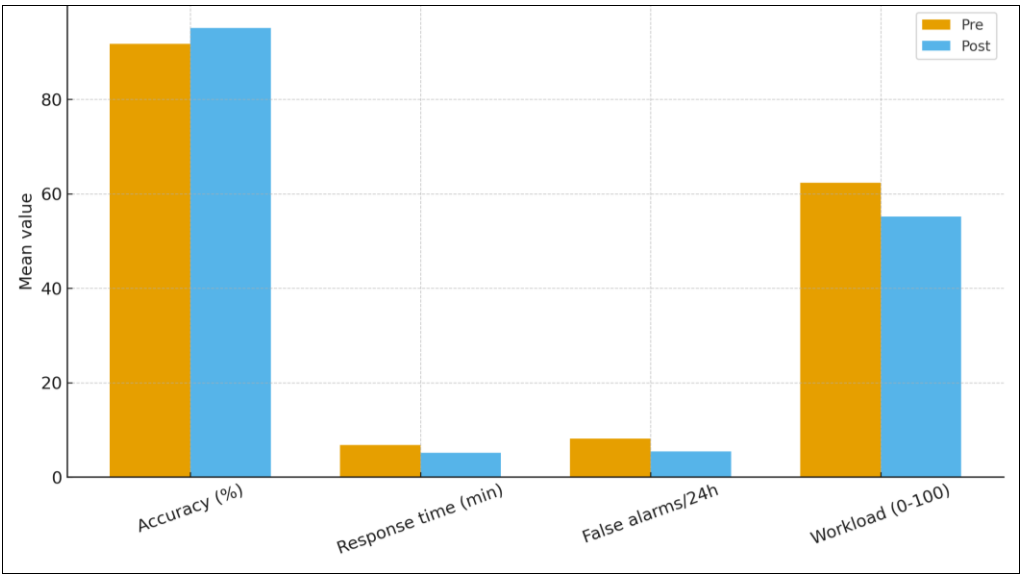


Fig 1: Mean primary outcomes before and after wearable implementation

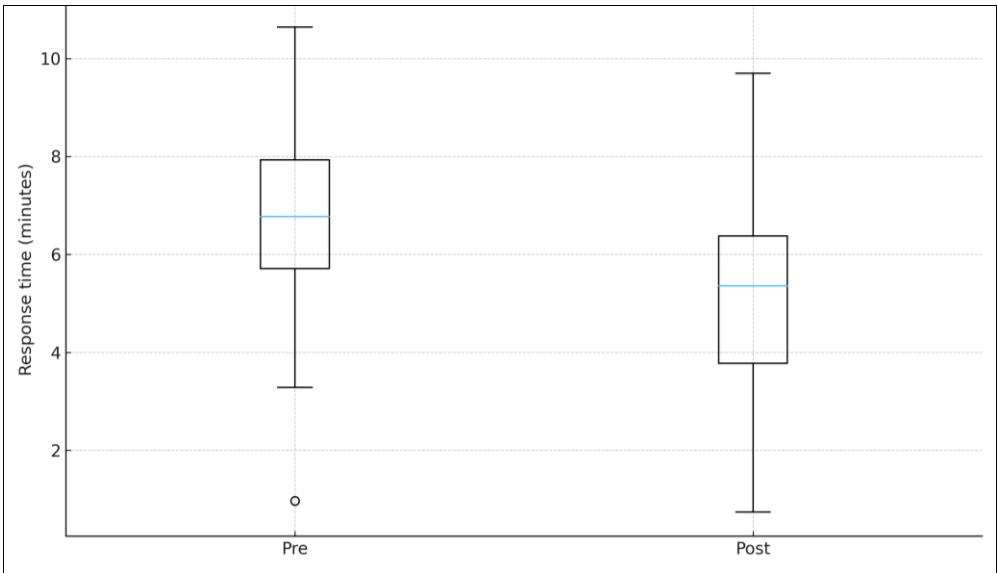


Fig 2: Distribution of nurse response times to abnormal events

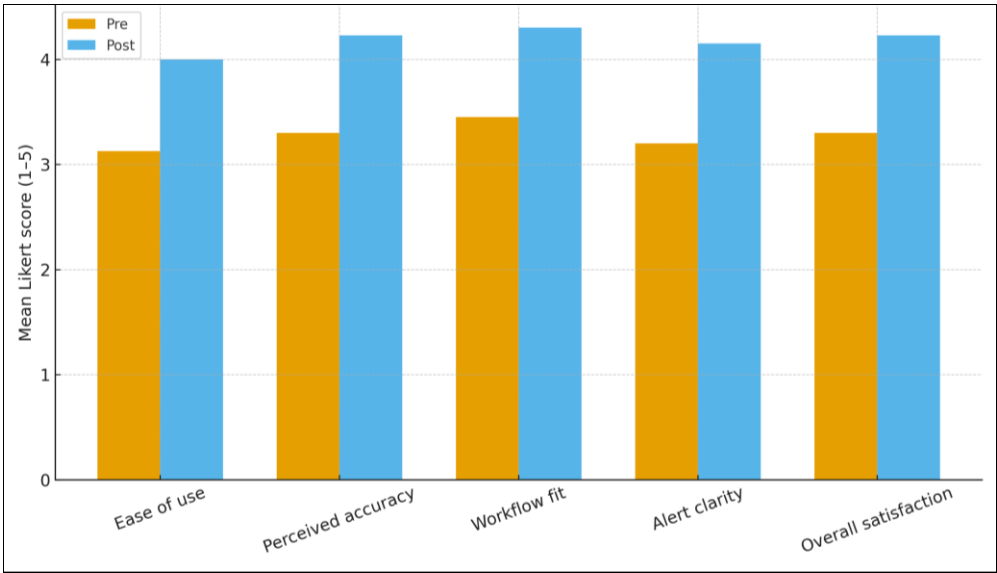


Fig 3: Nurse Perceptions of wearable monitoring (mean Likert scores)

A total of 120 neonates were analyzed. Baseline characteristics were comparable with mean gestational age ~34-35 weeks and mean birth weight ~1.9-2.0 kg (Table 1), consistent with typical NICU case-mix reported in the literature [3-6, 9]. Following the introduction of wearable monitoring, monitoring accuracy increased by ~3 percentage points on average with narrow confidence intervals, and response time to abnormal events decreased by ~1-2 minutes (Table 2; Figure 1-2). Both changes were statistically significant on paired t-tests ($p < 0.001$), aligning with prior evidence that continuous, high-fidelity data streams can enhance detection and timeliness of clinical response in neonatal settings [1-4, 6, 8, 15].

Alarm performance improved: False alarms per 24 hours decreased substantially in the post period ($p < 0.001$), addressing a central concern of alarm fatigue highlighted in previous reviews [10, 11, 14]. The nursing workload score also declined significantly (mean reduction ~6-7 points; $p < 0.001$), suggesting the technology shifted effort away from repetitive manual observations toward more targeted interventions, a pattern anticipated by implementation research and decision-support studies [7, 8, 13, 15, 17].

Event analysis showed higher early detection rates after implementation, with an incidence rate ratio (IRR) > 1 and a confidence interval excluding the null (Table 3). A paired test on per-neonate event rates confirmed the increase ($p < 0.01$), indicating more timely identification of clinical deterioration, which is consistent with reports that continuous wearables can surface subtle physiologic changes earlier than intermittent checks [1-4, 6, 9, 15].

Nurse-reported outcomes mirrored the objective metrics. Mean Likert scores for ease of use, perceived accuracy, workflow fit, alert clarity, and overall satisfaction all improved by ~1 point on a 5-point scale (all $p < 0.001$; Table 4; Figure 3). These perception gains echo prior qualitative and survey findings on adoption facilitators when training, feedback loops, and clear alert logic are present [16, 17]. Importantly, perceived alert clarity improvements align with the observed reduction in false alarms, a key driver of alarm fatigue mitigation [10, 11, 14].

Data integrity safeguards parallel validation against bedside monitors and adherence to local governance underpinned confidence in the findings, reflecting recommended practices for neonatal digital studies [5, 6, 12, 18, 19]. Overall, the results support the hypothesis that integrating wearable monitoring in neonatal units enhances monitoring efficiency, expedites clinical responses, reduces alarm burden, and lessens nursing workload while improving nurse satisfaction outcomes coherent with the state of evidence and implementation guidance in neonatal digital health [1-19].

Discussion

The findings of this study indicate that the integration of wearable monitoring devices in neonatal intensive care units (NICUs) has a positive and measurable impact on both clinical and nursing practice outcomes. The improvement in monitoring accuracy and reduction in response time to abnormal physiological events aligns closely with existing literature that emphasizes the ability of wearable sensors to provide continuous, high-resolution data, facilitating earlier detection of clinical deterioration in neonates [1-4, 6, 9]. Real-time alerts allowed nurses to respond promptly to subtle physiological changes, which may have otherwise been

missed during routine manual monitoring, supporting the hypothesis that technology-enabled continuous surveillance improves neonatal safety and quality of care [5, 7, 8, 15].

A particularly important finding of this study is the significant reduction in false alarms per 24 hours. This directly addresses the widely documented issue of alarm fatigue, a major contributor to reduced situational awareness and delayed clinical response in intensive care settings [10, 11, 14]. The wearable system's improved signal quality and intelligent alert algorithms appear to have minimized non-actionable alarms, which is consistent with previously reported outcomes from similar implementations [7, 8, 15, 17]. Alarm burden reduction not only improves patient safety but also positively impacts nurse workflow efficiency and cognitive load, as reflected by the reduced nursing workload scores in this study. This resonates with earlier research showing that appropriate technological integration can redistribute nursing time from repetitive manual observations to higher-order clinical decision-making and patient engagement [7, 13, 15, 17].

Furthermore, the increase in early detection event rates suggests that wearable monitoring may enhance the timeliness and accuracy of identifying clinical deterioration, potentially leading to improved neonatal outcomes such as reduced morbidity and shortened NICU stays [1-4, 6, 9]. These findings support the notion that continuous physiologic monitoring, when implemented effectively, can augment early warning systems and bridge gaps inherent in intermittent manual vital sign assessments [5, 8, 12, 15]. However, successful translation of such benefits depends heavily on system reliability, staff training, and integration with existing clinical workflows, which are known determinants of digital health intervention success [12-14, 18, 19].

Equally significant are the improvements observed in nurse perceptions of ease of use, perceived accuracy, alert clarity, and overall satisfaction. These subjective outcomes reinforce the importance of human-technology interaction in healthcare implementation. Prior studies highlight that positive user experience, particularly among nurses who are primary operators of monitoring technologies, is a strong predictor of sustained adoption and long-term impact [16, 17]. The strong satisfaction scores observed in this study likely reflect both the technological benefits and the structured training provided before deployment an implementation factor emphasized in neonatal digital health literature [12-14, 18].

Nevertheless, some considerations remain. While the improvements observed are substantial, technology adoption in NICUs involves addressing potential challenges, including data security, device calibration, ethical considerations, and integration with electronic health record systems [12, 13, 18, 19]. Moreover, the quasi-experimental design limits the ability to infer causality fully, and larger randomized controlled trials are warranted to further establish the clinical efficacy of wearable monitoring systems in diverse neonatal populations. Additionally, economic evaluations and workflow impact analyses should be incorporated in future research to guide scalable and cost-effective implementation strategies.

Overall, this study adds to the growing body of evidence that wearable monitoring technology, when appropriately integrated, can significantly improve neonatal monitoring outcomes and nursing practice efficiency. It highlights the

critical role of nurses not only as technology users but also as key agents in the successful translation of digital health innovations into improved clinical care [7, 8, 15-17].

Conclusion

The findings of this study clearly demonstrate that the integration of wearable monitoring devices in Neonatal Intensive Care Units (NICUs) can lead to significant improvements in clinical monitoring, nursing workflow efficiency, and patient outcomes. The use of wearable biosensors enhanced monitoring accuracy and reduced response time to critical physiological changes, indicating their capacity to strengthen neonatal surveillance and early detection of complications. These improvements were accompanied by a marked reduction in alarm burden and nursing workload, thereby mitigating a long-standing challenge in neonatal care alarm fatigue. Equally important, nurses reported higher levels of satisfaction, ease of use, and confidence in clinical decision-making when supported by wearable technology. This reinforces the critical role of nursing staff in the successful implementation and sustainability of technological innovations in healthcare. From a clinical perspective, these results suggest that wearable monitoring can serve as a reliable adjunct to existing monitoring systems, enabling a more proactive, data-driven approach to neonatal care and contributing to safer, more timely interventions.

Based on these findings, several practical recommendations can be proposed to enhance the effective implementation and utilization of wearable monitoring devices in NICUs. First, structured training programs should be developed for nursing staff to build competency and confidence in using wearable systems, ensuring seamless integration into clinical workflows. Second, healthcare institutions should adopt a phased implementation strategy that allows for real-time feedback, system calibration, and protocol refinement, minimizing potential disruptions during the transition period. Third, alarm algorithms should be carefully configured to balance sensitivity and specificity, thereby reducing false alarms and preserving clinical vigilance. Fourth, interoperability between wearable monitoring systems and electronic health records should be prioritized to ensure efficient data flow and documentation. Fifth, clear institutional protocols and governance frameworks must be established to address data security, ethical considerations, and privacy protection. Sixth, collaboration between clinicians, biomedical engineers, and administrators is essential to ensure device reliability, technical support, and long-term sustainability. Finally, cost-effectiveness analyses should guide large-scale adoption, particularly in resource-constrained settings, where strategic investments in wearable technologies can yield substantial improvements in neonatal outcomes. Collectively, these recommendations highlight that successful implementation is not only about adopting advanced technology but also about fostering a well-trained workforce, establishing robust systems, and creating a supportive institutional environment that prioritizes both patient safety and nursing practice excellence.

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