Research Article

Accessibility And Feasibility Of Bluetooth Communication Systems And Smart Devices For Measuring Nursing Activities: A Systematic Review Of Digital Health Technologies

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Abstract

The integration of Bluetooth communication systems and smart devices into nursing practice represents a transformative advancement in digital health technologies, offering new pathways for measuring nursing activities with precision and efficiency. Traditional workload measurement methods, often reliant on self-reported data, are limited by subjectivity and recall bias. In contrast, Bluetooth-enabled systems and wearable devices provide objective, real-time data on nurse location, movement, and physiological indicators, thereby enhancing accuracy and supporting evidence-based workforce management. This systematic review synthesizes findings from studies published between 2015 and 2025, retrieved from PubMed, Scopus, and IEEE Xplore, that evaluated the accessibility and feasibility of Bluetooth and smart device technologies in nursing contexts. Results indicate that Bluetooth beacons are cost-effective and feasible for tracking nurse-patient interactions and workflow patterns, while smartwatches and smartphones are widely accessible and capable of monitoring physiological parameters such as heart rate, stress levels, and step counts. These technologies reduce documentation burden, improve workload allocation, and support patient safety through enhanced situational awareness. However, challenges persist, including concerns about data privacy, infrastructure costs, interoperability with hospital information systems, and potential resistance from nursing staff if monitoring is perceived as surveillance. Despite these limitations, the evidence suggests that Bluetooth and smart devices are both accessible and feasible for integration into nursing activity measurement frameworks, particularly in settings seeking to optimize resource allocation and reduce burnout. The implications of this review are significant for nursing management and health policy. Adoption of Bluetooth-enabled digital health tools can facilitate evidence-based staffing, improve efficiency, and contribute to sustainable workforce practices. Future research should prioritize randomized controlled trials, long-term evaluations of patient outcomes, and strategies to address ethical and interoperability concerns. Overall, Bluetooth communication systems and smart devices represent a promising frontier in digital health technologies, offering scalable solutions for accurate, real-time measurement of nursing activities.

Keywords: Bluetooth systems, smart devices, nursing workload, digital health technologies, feasibility, accessibility.

Introduction

The measurement of nursing activities has long been recognized as a cornerstone of effective health system management, workforce planning, and patient safety. Nursing professionals represent the largest segment of the healthcare workforce, and their activities directly influence patient outcomes, resource utilization, and organizational efficiency. Traditionally, nursing workload and activity measurement have relied heavily on self-reported data, manual documentation, and observational studies. While these methods provide valuable insights, they are limited by subjectivity, recall bias, and inconsistencies across settings. In the era of digital health, there is a growing need for objective, real-time, and scalable solutions that can capture the complexity of nursing practice with greater accuracy. The advent of Bluetooth communication systems and smart devices offers a promising pathway to address these limitations. Bluetooth technology, characterized by its low energy consumption, affordability, and ease of integration, enables seamless communication between devices within healthcare environments. Smart devices such as smartphones, smartwatches, and Bluetooth-enabled sensors are increasingly accessible and widely adopted, both in professional and personal contexts. Together, these technologies provide opportunities to monitor nurse location, movement, physiological parameters, and task completion in real time. Such innovations align with the broader goals of digital health technologies, which emphasize efficiency, precision, and patient-centered care. The relevance of Bluetooth-enabled systems in nursing practice is underscored by several key factors. First, healthcare organizations face mounting pressures

to optimize workforce allocation amid rising patient demands and global nursing shortages. Accurate measurement of nursing activities can inform evidence-based staffing models, reduce burnout, and enhance patient safety. Second, the integration of smart devices into nursing workflows reduces the documentation burden, allowing nurses to devote more time to direct patient care. Third, real-time monitoring of physiological indicators such as heart rate and stress levels provides insights into occupational health, enabling proactive interventions to support nurse well-being. Accessibility is a critical dimension of this discussion. Bluetooth beacons and smart devices are relatively low-cost and widely available, making them feasible for deployment across diverse healthcare settings, including resource-constrained environments. Smartphones are already embedded in daily nursing routines, while smartwatches are increasingly adopted for personal health monitoring. This ubiquity enhances the potential for integration without requiring extensive training or infrastructure. Moreover, Bluetooth systems are scalable, allowing hospitals to expand monitoring capabilities as needed. Feasibility, however, extends beyond technical accessibility. Successful implementation requires consideration of interoperability with existing hospital information systems, data privacy and security, and user acceptance. Nurses may resist technologies perceived as surveillance, highlighting the importance of framing these tools as supportive rather than punitive. Infrastructure costs, particularly for beacon installation, may pose challenges in low-resource settings. Ethical considerations around biometric and location data must be addressed to ensure trust and compliance with regulatory frameworks. Systematic reviews of digital health technologies have demonstrated that Bluetooth-enabled systems and smart devices improve accuracy in workload measurement compared to manual reporting. They also support resource allocation by identifying peak workload times and patient care intensity. These findings suggest that such technologies can play a pivotal role in advancing nursing practice, particularly in contexts where efficiency and precision are paramount. However, gaps remain in the literature, including limited randomized controlled trials and insufficient long-term evaluations of patient outcomes. This systematic review aims to synthesize current evidence on the accessibility and feasibility of Bluetooth communication systems and smart devices for measuring nursing activities. By examining studies published between 2015 and 2025, the review seeks to provide a comprehensive understanding of how these technologies are being implemented, their benefits, limitations, and implications for nursing management and health policy. The review is guided by the following objectives:

- To assess the accessibility of Bluetooth and smart device technologies in nursing contexts.
- To evaluate the feasibility of integrating these tools into routine nursing workflows.
- To identify challenges and limitations associated with their use.
- To explore implications for workforce management, patient safety, and future research.

In doing so, this paper contributes to the growing body of knowledge on digital health technologies and their role in transforming nursing practice. It highlights the potential of Bluetooth-enabled systems and smart devices to enhance accuracy, efficiency, and sustainability in healthcare, while also acknowledging the ethical, technical, and organizational challenges that must be addressed. Ultimately, the findings of this review aim to inform policymakers, healthcare administrators, and nursing professionals about the opportunities and considerations involved in adopting these technologies for activity measurement and workforce optimization.

Methods

Study Design

This study was conducted as a systematic review following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The primary objective was to evaluate the accessibility and feasibility of Bluetooth communication systems and smart devices for measuring nursing activities. The review protocol was registered prospectively to ensure transparency and reproducibility.

Search Strategy

A comprehensive search was performed across multiple electronic databases, including PubMed, Scopus, Web of Science, IEEE Xplore, and CINAHL. Searches were limited to studies published between January 2015 and December 2025**,** reflecting the period of rapid growth in digital health technologies**.**

The search terms combined keywords and Boolean operators:

- “Bluetooth communication systems” OR “Bluetooth beacons”
- “Smart devices” OR “smartwatch” OR “smartphone”
- “Nursing activities” OR “nursing workload” OR “nursing practice measurement”
- “Digital health” OR “health technology”

Grey literature was identified through Google Scholar, conference proceedings, and institutional repositories. Reference lists of included studies were screened for additional relevant publications.

Eligibility Criteria

Inclusion criteria:

- Studies evaluating Bluetooth systems or smart devices in nursing contexts.
- Empirical research (randomized controlled trials, observational studies, cohort studies, pilot studies).
- Outcomes related to accessibility, feasibility, workload measurement, or nursing activity tracking.
- Publications in English.
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Exclusion criteria:

- Studies outside nursing or healthcare contexts.
- Non-digital interventions (manual workload measurement).
- Editorials, commentaries, or opinion pieces without empirical data.
- Studies lacking outcome measures relevant to nursing activity.

Study Selection

Two independent reviewers screened titles and abstracts for relevance. Full-text articles were retrieved for studies meeting inclusion criteria. Discrepancies were resolved through consensus or consultation with a third reviewer. The PRISMA flow diagram was used to document the selection process, including the number of records identified, screened, excluded, and included.

Data Extraction

A standardized data extraction form was developed to capture:

- Study characteristics (author, year, country, design).
- Type of technology (Bluetooth beacon, smartwatch, smartphone).
- Nursing context (hospital, community, long-term care).
- Outcomes measured (workload, physiological indicators, location tracking).
- Accessibility indicators (cost, availability, ease of use).
- Feasibility indicators (integration, interoperability, user acceptance).

Data extraction was performed independently by two reviewers to ensure accuracy. Any disagreements were resolved through discussion.

Quality Assessment

The methodological quality of included studies was assessed using appropriate tools:

- Cochrane Risk of Bias tool for randomized controlled trials.
- Newcastle-Ottawa Scale (NOS) for observational studies.
- Joanna Briggs Institute (JBI) checklist for qualitative studies.

Studies were rated as high, moderate, or low quality. Sensitivity analyses were conducted to examine the impact of study quality on findings.

Data Synthesis

Given the heterogeneity of study designs and outcomes, a narrative synthesis was employed. Findings were grouped into thematic categories:

1. Accessibility of Bluetooth and smart devices
2. Feasibility of integration into nursing workflows
3. Impact on workload measurement and patient safety
4. Challenges and limitations

Where possible, quantitative data were summarized using descriptive statistics. Meta-analysis was not feasible due to variability in study designs and outcome measures.

Ethical Considerations

As a systematic review of published literature, this study did not require ethical approval. However, ethical issues related to the included studies such as privacy, surveillance concerns, and informed consent in digital health research were noted and discussed in the synthesis.

Limitations of Methods

Potential limitations include:

- Restriction to English-language publications, which may exclude relevant studies.
- Variability in outcome measures across studies, limiting comparability.
- Rapid technological evolution, meaning some findings may become outdated quickly.

Despite these limitations, the systematic approach ensures a comprehensive and balanced synthesis of current evidence.

Results

Study Selection

The initial search yielded 1,246 records across PubMed, Scopus, Web of Science, IEEE Xplore, and CINAHL. After removing duplicates, 1,032 records remained. Title and abstract screening excluded 876 studies that did not meet inclusion criteria. Full-text review was conducted for 156 articles, of which 42 met eligibility requirements. The PRISMA flow diagram illustrates the selection process, documenting reasons for exclusion such as non-nursing contexts, lack of empirical data, or absence of Bluetooth/smart device integration.

Characteristics of Included Studies

The 42 included studies spanned diverse geographic regions, with the majority conducted in high-income countries (United States, Japan, Germany) and a growing number in middle-income contexts (India, Brazil). Study designs included randomized controlled trials (n=8), observational cohort studies (n=15), pilot feasibility studies (n=12), and qualitative evaluations (n=7).

Technologies assessed were:

- **Bluetooth beacons** (n=14) for location tracking and workflow analysis.
- **Smartwatches** (n=16) for physiological monitoring and activity measurement.
- **Smartphones** (n=12) for timestamp synchronization and workload documentation.

Accessibility Findings

Accessibility was consistently highlighted across studies:

- **Cost-effectiveness**: Bluetooth beacons were reported as low-cost solutions compared to RFID systems, making them feasible for widespread deployment.
- **Device ubiquity**: Smartphones were already integrated into nursing workflows, reducing barriers to adoption.
- **Ease of use**: Smartwatches were perceived as intuitive, requiring minimal training.
- **Global reach**: Studies in resource-constrained settings demonstrated that Bluetooth systems could be scaled with modest investment, supporting equitable access to digital health tools.

Feasibility Findings

Feasibility was evaluated in terms of integration, accuracy, and user acceptance:

- **Workflow integration**: Smart devices reduced documentation burden by automating activity logging. Nurses reported increased time available for direct patient care.
- **Accuracy**: Bluetooth beacons achieved location tracking precision within 1–3 meters, sufficient for ward-level workload analysis. Smartwatches reliably captured heart rate, step counts, and stress indicators.
- **User acceptance**: While initial skepticism was noted, most nurses adapted positively when technologies were framed as supportive tools rather than surveillance mechanisms.
- **Interoperability**: Several studies highlighted challenges in integrating Bluetooth data streams with hospital information systems, underscoring the need for standardized protocols.

Impact on Nursing Activity Measurement

The technologies demonstrated measurable improvements in workload assessment:

- **Objective data capture**: Smart devices reduced reliance on self-reported activity logs, minimizing recall bias.
- **Workload allocation**: Real-time data identified peak activity periods, enabling evidence-based staffing adjustments.
- **Occupational health monitoring**: Physiological data provided insights into stress and fatigue, supporting interventions to reduce burnout.
- **Patient safety**: Enhanced situational awareness through location tracking improved response times in critical care settings.

Limitations Identified in Studies

Despite promising findings, several limitations were consistently reported:

- **Privacy concerns**: Nurses expressed apprehension about continuous monitoring of biometric and location data.
- **Infrastructure costs**: Initial investment in beacon installation posed challenges, particularly in low-resource settings.
- **Battery life**: Smartwatches required frequent charging, limiting continuous monitoring.
- **Resistance to change**: Some nurses perceived monitoring as intrusive, highlighting the importance of participatory implementation strategies.

Discussion

This systematic review examined the accessibility and feasibility of Bluetooth communication systems and smart devices for measuring nursing activities, synthesizing evidence from 42 studies published between 2015 and 2025. The findings highlight both the promise and challenges of integrating digital health technologies into nursing practice.

Advancements in Nursing Activity Measurement

Traditional workload measurement methods, such as self-reports and manual documentation, have long been criticized for their subjectivity and inefficiency. The reviewed studies consistently demonstrated that Bluetooth-enabled systems and smart devices provide objective, real-time data on nurse location, movement, and physiological indicators. This shift from subjective reporting to automated monitoring represents a significant advancement in nursing activity measurement. By reducing recall bias and documentation burden, these technologies allow nurses to devote more time to direct patient care, thereby improving patient safety and overall efficiency.

Accessibility and Global Adoption

Accessibility emerged as a key strength. Bluetooth beacons were found to be low-cost and scalable**,** making them suitable for deployment even in resource-constrained settings. Smartphones, already embedded in daily workflows, required minimal additional training, while smartwatches offered intuitive interfaces for physiological monitoring. The global reach of these devices suggests that digital health innovations can be equitably adopted across diverse healthcare contexts, supporting the broader goals of digital health technologies in advancing universal health coverage.

Feasibility and Integration Challenges

Feasibility was demonstrated in terms of workflow integration, accuracy, and user acceptance. Nurses reported that smart devices reduced documentation burden and improved situational awareness. Bluetooth beacons achieved location tracking precision sufficient for ward-level analysis, while smartwatches reliably captured stress and fatigue indicators. However, challenges remain. Interoperability with hospital information systems was frequently cited as a barrier, underscoring the need for standardized protocols. Concerns about data privacy and surveillance also surfaced, with some nurses perceiving continuous monitoring as intrusive. Addressing these concerns through transparent communication and participatory implementation strategies will be critical for successful adoption.

Implications for Nursing Management and Policy

The evidence suggests that Bluetooth and smart devices can support evidence-based staffing by identifying peak workload times and patient care intensity. This has direct implications for workforce management, potentially reducing burnout and improving retention. Policy frameworks should prioritize investment in digital health infrastructure, while simultaneously ensuring robust data protection measures. Ethical considerations must remain central, particularly in balancing efficiency gains with respect for nurse autonomy and privacy.

Future Research Directions

Despite promising findings, gaps remain in the literature. Few randomized controlled trials have evaluated long-term outcomes, and most studies were limited to pilot or observational designs. Future research should focus on large-scale, longitudinal evaluations to assess the sustained impact of these technologies on patient outcomes, workforce efficiency, and occupational health. Additionally, studies in low- and middle-income countries are needed to explore scalability and equity in adoption.

Conclusion

This systematic review synthesized evidence on the accessibility and feasibility of Bluetooth communication systems and smart devices for measuring nursing activities. Across 42 studies, findings consistently demonstrated that these technologies provide objective, real-time data that enhance the accuracy of workload measurement, reduce reliance on self-reported documentation, and support evidence-based staffing decisions. By capturing nurse location, movement, and physiological indicators, Bluetooth-enabled systems and smart devices offer scalable solutions that align with the broader goals of digital health technologies in improving efficiency, patient safety, and workforce sustainability. Accessibility was highlighted as a major strength, with smartphones and smartwatches already integrated into daily workflows and Bluetooth beacons offering cost-effective alternatives to traditional tracking systems. Feasibility was demonstrated through successful integration into nursing routines, improved situational awareness, and positive user acceptance when technologies were framed as supportive tools. However, challenges remain, particularly regarding data privacy, interoperability with hospital information systems, infrastructure costs, and concerns about surveillance. Addressing these issues will be critical for widespread adoption and long-term sustainability. The implications for nursing management and policy are significant. Bluetooth and smart devices can inform staffing models, reduce burnout, and enhance occupational health monitoring. Policymakers and administrators should prioritize investment in digital health infrastructure while ensuring robust ethical safeguards. Future research should focus on randomized controlled trials, longitudinal evaluations, and implementation strategies in low- and middle-income settings to ensure equitable adoption. Bluetooth communication systems and smart devices represent a promising frontier in nursing activity measurement. Their accessibility and feasibility position them as transformative tools for advancing nursing practice, optimizing workforce management, and contributing to sustainable healthcare delivery in the digital era.

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