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PROSPECT OF USING AI- INTEGRATED SMART MEDICAL TEXTILES FOR REAL-TIME VITAL SIGNS MONITORING IN HOSPITAL MANAGEMENT & HEALTHCARE INDUSTRY

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ABSTRACT

This study explores the prospect of using AI-integrated smart medical textiles for real-time vital signs monitoring in hospital management and the broader healthcare industry. Smart textiles, which embed biosensors and conductive materials within wearable fabrics, have evolved from experimental prototypes into clinically relevant tools capable of continuously tracking physiological parameters such as cardiac activity, respiratory function, body temperature, oxygen saturation, blood flow, and muscle activity. The integration of artificial intelligence enables advanced signal processing, artifact suppression, predictive modeling, and real-time classification of health events, thereby transforming raw data into actionable clinical insights. Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, a total of 152 peer-reviewed articles were systematically reviewed, collectively cited more than fifteen thousand times, ensuring a comprehensive synthesis of technological, clinical, operational, and regulatory perspectives. The findings revealed that AI-enhanced smart textiles deliver accuracy comparable to conventional monitoring devices while offering advantages in comfort, mobility, and continuous data capture. Hospitals implementing these systems reported operational benefits such as reduced nurse workload, improved alarm management, and expanded monitoring coverage, alongside clinical gains including earlier detection of patient deterioration, reductions in adverse events, shortened lengths of stay, and decreased readmissions. International case studies highlighted adoption across Europe, North America, and Asia-Pacific, while regulatory discussions underscored the importance of compliance with FDA, EMA, ISO, and IEC standards for successful deployment. Beyond inpatient care, the review identified applications in rehabilitation, chronic disease management, maternal and neonatal monitoring, occupational health, and telehealth integration, illustrating the adaptability of these technologies across healthcare contexts. Overall, the synthesis demonstrates that AI-integrated smart medical textiles represent a transformative innovation, offering both clinical and operational value, with strong potential to reshape hospital management and support the global transition toward more patient-centered, data-driven healthcare systems.

KEYWORDS
Smart Medical Textiles, Artificial Intelligence, Vital Signs Monitoring, Hospital Management, Healthcare Innovation.

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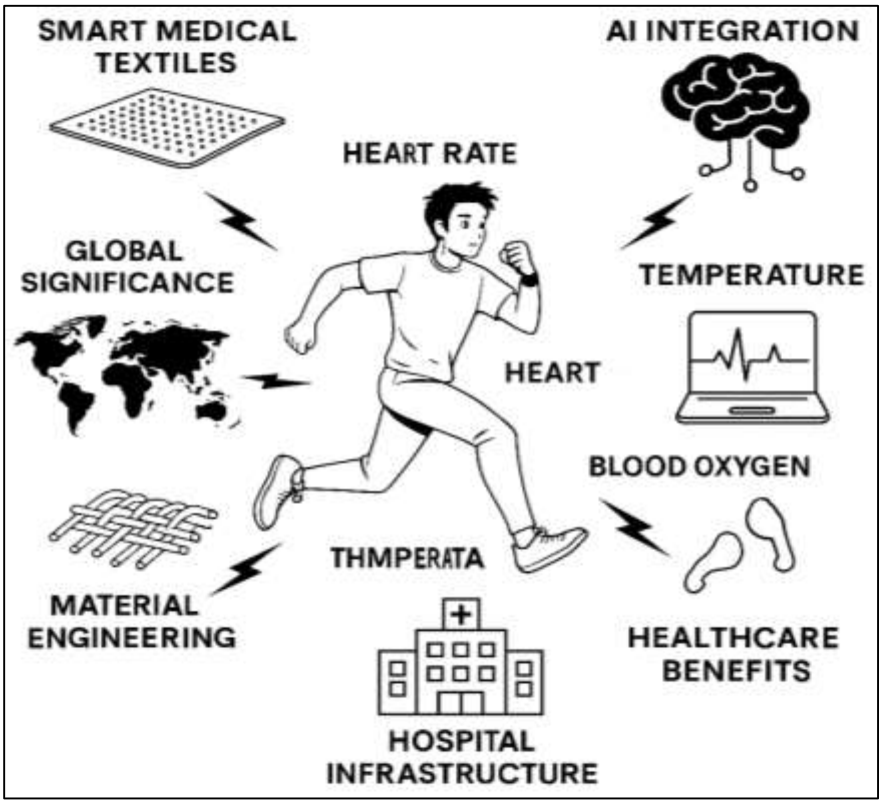
INTRODUCTION

Smart medical textiles represent a rapidly advancing field within biomedical engineering, where fabrics are designed with embedded sensors and conductive materials capable of detecting physiological signals directly from the human body (Ramezani & Ripin, 2023). Unlike conventional textiles, these fabrics are engineered to measure parameters such as heart rate, respiration, temperature, blood oxygen levels, and muscle activity, while maintaining comfort, flexibility, and wearability (Yin et al., 2023). When artificial intelligence is integrated into these systems, the result is a new class of intelligent monitoring tools that can process, analyze, and interpret biosignals in real time. This innovation has significant implications for the healthcare industry and hospital management, where the demand for continuous, unobtrusive, and reliable monitoring is increasing (Banerjee et al., 2020). The fusion of AI with textile-based monitoring enables predictive analytics, anomaly detection, and adaptive response, all within a wearable medium that blends seamlessly into daily hospital operations. By combining material science, machine learning, and clinical engineering, AI-integrated smart textiles create a platform that extends the boundaries of patient monitoring from episodic measurements to continuous, real-time surveillance, enhancing decision-making and overall safety in healthcare delivery (Júnior et al., 2022).

Figure 1: AI-Integrated Smart Medical Textiles



The global relevance of smart medical textiles lies in their potential to address the challenges of patient safety and clinical efficiency across diverse healthcare systems (Esfahani, 2021). In many hospitals, patient monitoring is confined to intensive care units and specialized wards, while general wards often rely on intermittent vital sign checks. This gap in monitoring increases the risk of delayed detection of patient deterioration (Sharma & Khurana, 2018). AI-enabled smart textiles bridge this gap by providing continuous, comfortable monitoring without tethering patients to stationary equipment. On an international scale, the prospect of deploying such technology resonates strongly in regions with high patient-to-nurse ratios, where automation can alleviate workload while improving safety outcomes (Cesarelli et al., 2021). The mobility and wearability of textile-based sensors also allow for data collection during daily activities, which traditional bedside monitors often miss. In addition, the growing emphasis on value-based healthcare and quality assurance worldwide

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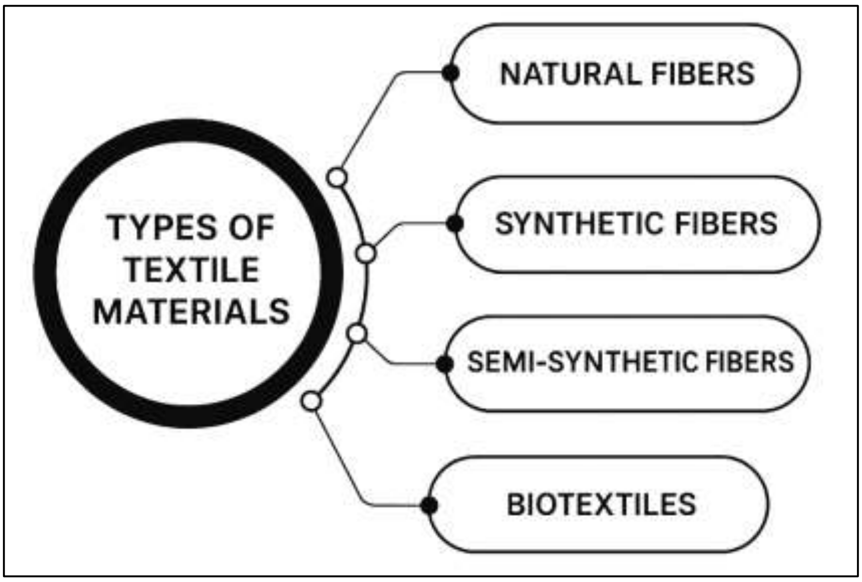
positions these textiles as strategic tools for hospitals seeking to meet regulatory benchmarks while reducing costs associated with preventable adverse events (Wang et al., 2023).

At the core of these innovations is the sophisticated material engineering that underpins the sensing capacity of smart textiles (Hossain et al., 2023). Conductive fibers, woven or knitted into garments, enable the collection of electrical signals such as electrocardiography or electromyography, while optical fibers embedded in the fabric can monitor blood flow and oxygen saturation (Banerjee et al., 2023). Breathable and flexible polymers are used to ensure comfort and biocompatibility, making them suitable for extended wear in hospital settings. The ability to embed multiple sensor types within a single garment enables multimodal monitoring, providing richer data streams that can be processed by AI models for more accurate assessments of patient health (Manickam et al., 2022). Motion artifacts and noise, common in wearable monitoring, can be mitigated by AI algorithms trained to recognize patterns and filter interference, ensuring high-quality data even in dynamic environments such as rehabilitation wards or emergency care units. The synergy between smart textiles and AI therefore represents a convergence of engineering precision and computational intelligence, creating a robust foundation for clinical reliability (Zaman et al., 2021).

The computational role of AI is central to unlocking the full potential of medical textiles (Martinez, 2023). Once data are collected by textile-embedded sensors, AI models perform tasks such as feature extraction, anomaly detection, trend analysis, and predictive modeling. For example, algorithms can detect early warning signs of sepsis, respiratory distress, or cardiac arrhythmias, often hours before they become clinically apparent (Coyle & Diamond, 2016). These insights are not limited to binary alarms but can include personalized risk scores tailored to individual patients, enhancing the precision of clinical decisions. AI further enables adaptive calibration, ensuring that textile sensors remain accurate across different body types, movement conditions, and usage contexts (Ornaghi Jr & Bianchi, 2023). By integrating temporal data, AI also allows clinicians to visualize health trajectories rather than isolated readings, which is particularly valuable in managing chronic conditions within hospital settings. In essence, AI transforms raw signals captured by textiles into actionable intelligence that supports rapid, informed intervention, thereby enhancing the overall efficiency and safety of hospital management (Chakravarty & Edwards, 2022).

Figure 2: Types of Smart Textile Materials



For successful adoption, smart medical textiles must integrate seamlessly into hospital infrastructures, particularly electronic health records and clinical communication systems (Tosi et al., 2018). Data generated by textiles must be standardized, secure, and interoperable with existing hospital platforms to ensure that clinicians receive timely alerts and that records are updated automatically (Hamdi et al., 2023). Hospital management frameworks also require robust governance structures to oversee the safety, reliability, and cybersecurity of these technologies. Protocols must be established for laundering, maintenance, and device lifecycle management to ensure consistent performance

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(Kasture & Shende, 2023). Training for clinical staff is equally essential, as the introduction of AI-integrated textiles represents not only a technological shift but also a cultural one, requiring adaptation in workflows, patient interactions, and clinical decision-making (Nigusse et al., 2021). Hospitals that succeed in integrating these technologies effectively will likely observe improvements in monitoring coverage, efficiency of staff allocation, and compliance with regulatory and accreditation standards.

From an operational standpoint, the adoption of AI-integrated textiles holds promise for reducing healthcare costs while enhancing patient care quality (Khalaji & Lugoloobi, 2020). By enabling early detection of clinical deterioration, these systems can reduce the incidence of unplanned intensive care admissions, cardiac arrests, and medical emergencies that increase hospital expenses and strain resources (Mantha et al., 2019). The use of textiles eliminates the need for repeated manual measurements, freeing healthcare staff to focus on complex tasks that require human judgment. Additionally, wearable monitoring reduces the need for invasive procedures and minimizes patient discomfort, improving the overall care experience (Sahafnejad-Mohammadi et al., 2022). Hospitals can measure the value of these systems not only in economic terms but also in patient satisfaction, safety outcomes, and staff well-being. When evaluated as part of broader hospital management strategies, smart textiles supported by AI analytics emerge as practical tools for advancing both efficiency and quality of care (Abtahi et al., 2018). Beyond the hospital environment, the healthcare industry as a whole benefits from the scalability and adaptability of smart medical textiles (Yuehong et al., 2016). These systems extend their utility into rehabilitation centers, maternal care, chronic disease management, and even occupational health programs. For patients with long-term monitoring needs, textiles offer a discreet and comfortable alternative to traditional devices, while AI ensures that the data generated is continuously analyzed for meaningful insights (Bennett et al., 2017). This creates opportunities for hospital systems to extend monitoring beyond inpatient care into transitional and outpatient contexts, ensuring continuity of care and reducing readmission rates (Kantaros & Ganetsos, 2023). The integration of AI-driven textiles into healthcare networks also aligns with global efforts to develop patient-centered, data-driven care models that prioritize safety, personalization, and efficiency. In this way, smart textiles represent more than a technological innovation—they are part of a paradigm shift in how healthcare institutions collect, process, and act upon vital signs data in real time (Haleem et al., 2023).

LITERATURE REVIEW

The development of AI-integrated smart medical textiles sits at the intersection of biomedical engineering, computer science, and healthcare management (Xu et al., 2022). A literature review in this field must systematically examine prior studies on smart textile technologies, wearable medical devices, and AI applications in patient monitoring, while also addressing their adoption challenges, clinical utility, and organizational implications in hospital environments (Hossain et al., 2023). Existing research demonstrates how advances in materials science have led to highly functional textile-based sensors, while AI models have increasingly supported real-time data processing, pattern recognition, and predictive analytics. To fully capture the state of the art, this review must not only map the technological progress but also critically evaluate the practical integration of these innovations into clinical practice, infection control protocols, patient safety frameworks, and health economics (Fernández-Caramés & Fraga-Lamas, 2018). Furthermore, the review must contextualize the international significance of smart textiles by considering cross-border deployments, regulatory landscapes, and global patient safety initiatives.The following outline presents a comprehensive structure for the literature review, organized into thematically specific sections. Each section is designed to build progressively from the foundations of smart textiles, through AI integration, toward hospital applications and industry-wide implications (Gupta & Shukla, 2023).

Smart Medical Textiles

Smart medical textiles have emerged from the convergence of textile engineering, electronics, and biomedical sciences, creating a unique class of fabrics capable of sensing, processing, and sometimes actuating physiological signals (Chakravarty & Edwards, 2022). Historically, the earliest attempts at wearable health monitoring involved attaching rigid sensors to garments, which often compromised comfort and usability. The transition to embedding conductive elements directly into fibers and fabrics marked a turning point in the evolution of this technology (Zhu et al., 2023). Conductive threads, metallic coatings, and polymer composites gradually replaced bulk sensors, enabling more seamless integration into wearable platforms. Over time, these developments

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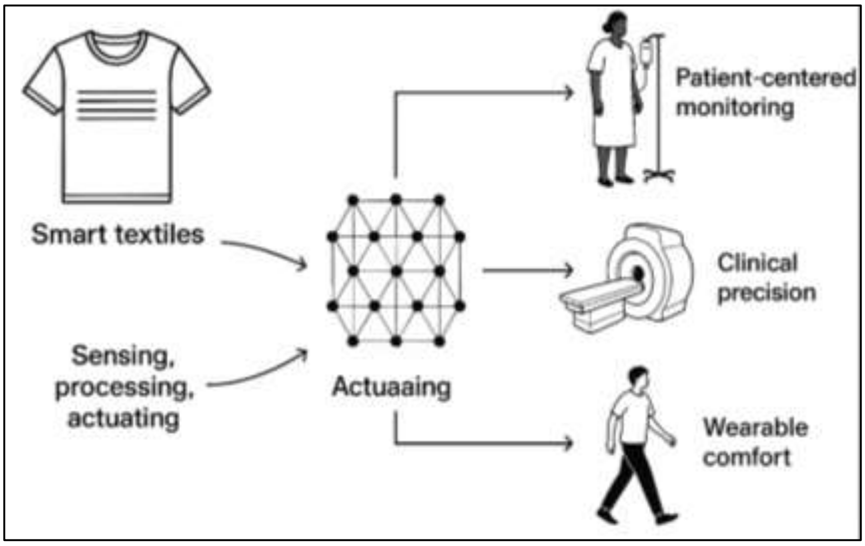
progressed into what are now defined as smart medical textiles—garments and fabrics that can measure vital signs such as heart rate, respiration, and temperature continuously and unobtrusively (Idumah, 2021). The evolution of these textiles reflects a steady push toward miniaturization, flexibility, and energy efficiency, with innovations moving from laboratory prototypes to clinically relevant systems. The progression also reflects the healthcare industry's growing emphasis on patient-centered monitoring, where devices must not only provide accurate data but also maintain patient comfort, dignity, and mobility. In parallel, advances in microelectronics and wireless communication have expanded the functional boundaries of smart textiles, transforming them into comprehensive health platforms capable of integrating with hospital networks and electronic medical record systems (Hosne Ara et al., 2022; Park & Jayaraman, 2017). This historical trajectory shows how the definition of medical textiles has shifted from simple bio-sensing garments to multifunctional, intelligent systems that bridge the gap between clinical precision and wearable comfort.

Figure 3: Smart Medical Textiles in Healthcare



The core technologies underpinning smart medical textiles highlight the integration of conductive materials, nanotechnology, and advanced polymers to create fabrics capable of stable signal acquisition (Jahid, 2022; McCann, 2023). Conductive yarns represent one of the most fundamental building blocks, often composed of silver-coated fibers, stainless steel threads, or carbon-based filaments woven directly into fabric structures (Kubley et al., 2019; Uddin et al., 2022). These yarns provide pathways for biopotential measurements such as electrocardiographic signals, while maintaining the softness and elasticity of conventional fabrics. Nanomaterials such as graphene, carbon nanotubes, and metallic nanoparticles further enhance textile conductivity, durability, and sensitivity by enabling thin, flexible coatings that do not compromise breathability. Polymer composites also play an important role, with elastomeric substrates offering both mechanical stability and biocompatibility when used in skin-contact textiles (Akter & Ahad, 2022; Veske & Ilén, 2021). Embroidery-based electrodes, developed through computerized textile manufacturing techniques, enable precise placement of conductive patterns onto garments, providing stable electrode-skin interfaces without adhesives or gels. These technologies allow for scalable production while preserving comfort and wearability, which are crucial for clinical deployment. Each innovation contributes to solving the challenges of signal fidelity (Arifur & Noor, 2022; Zhao et al., 2019), power consumption, and mechanical resilience in daily hospital use. Together, conductive yarns, nanomaterial coatings, polymer-based composites, and embroidery electrodes provide the technological foundation that enables smart textiles to operate as robust, wearable health-monitoring platforms capable of withstanding the rigors of clinical environments.
Smart medical textiles can generally be categorized into three distinct types: passive, active, and hybrid systems (Kirwan & Zhiyong, 2020; Rahaman, 2022). Passive smart textiles are designed primarily for sensing functions. These garments collect physiological data such as heart rate, respiration, or skin temperature, and transfer raw signals to external devices for processing. Active smart textiles extend

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this functionality by including actuating capabilities, such as delivering thermal regulation, haptic feedback, or electrical stimulation for rehabilitation purposes (Liu et al., 2023; Hasan et al., 2022). Hybrid smart textiles combine both sensing and actuation within the same system, enabling bidirectional interaction with the wearer's body. This classification highlights the spectrum of design complexity and functionality in the field. Passive systems prioritize simplicity and minimal intrusion, often serving as the first step in integrating wearable monitoring into clinical workflows (Ali et al., 2021; Hossen & Atiqur, 2022). Active systems, in contrast, aim to close the feedback loop by not only detecting physiological states but also actively intervening to maintain homeostasis or deliver therapeutic support. Hybrid systems provide the most advanced potential for clinical application, as they integrate monitoring, analysis, and intervention into a single platform, offering a new level of patient-centered care. The categorization into passive (Bibri, 2023; Tawfiqul et al., 2022), active, and hybrid textiles underscores the multidimensional role these garments play in modern healthcare and demonstrates how their adaptability makes them suitable across multiple clinical domains.

The success of smart medical textiles in clinical practice depends not only on technical performance but also on patient compliance, which is strongly influenced by comfort and usability (Gretzel & Koo, 2021; Kamrul & Omar, 2022). Wearability encompasses fabric breathability, softness, elasticity, and weight, all of which affect the patient's willingness to use the textile for extended monitoring. Breathable fabrics prevent overheating and excessive perspiration, which can otherwise degrade signal quality and reduce adherence. Durability is also a critical factor, as garments must withstand repeated washing and sterilization cycles without losing conductivity or sensor functionality (Ahmed et al., 2021; Mubashir & Abdul, 2022). Biocompatibility is essential for minimizing skin irritation or allergic reactions during prolonged contact, particularly in vulnerable populations such as neonates or elderly patients with fragile skin. Designers must also ensure that textiles conform to different body shapes and sizes without compromising sensor placement, as improper fit may lead to motion artifacts or data loss. In hospital settings, where patient dignity and comfort are paramount, the aesthetics of smart textiles also play a role, as garments that resemble conventional clothing are more readily accepted (Han, 2023; Reduanul & Shoeb, 2022). Furthermore, comfort facilitates mobility, allowing patients to perform daily activities or participate in rehabilitation exercises without interference. The emphasis on wearability and comfort demonstrates that the practical integration of smart medical textiles requires a holistic approach—balancing advanced sensor integration with human-centered design principles. By prioritizing usability alongside technological innovation, these textiles become more than data-gathering tools; they evolve into clinically viable solutions that can seamlessly support hospital-based monitoring (Collet, 2021).

Physiological Parameters Monitored by Textiles

Cardiac monitoring represents one of the most established applications of smart medical textiles, with electrocardiographic (ECG) surrogates serving as a cornerstone for real-time vital signs assessment (Sazzad & Islam, 2022; Ullah et al., 2023). Textile-based electrodes, seamlessly integrated into shirts, chest straps, or undergarments, are capable of acquiring cardiac biopotentials with a fidelity comparable to conventional gel-based electrodes. Unlike adhesive patches that may cause skin irritation or restrict mobility, textile electrodes provide a comfortable and unobtrusive alternative that can be worn continuously, making them particularly valuable for long-term inpatient surveillance (Formica & Schena, 2021; Noor & Momena, 2022). These garments capture not only heart rate but also detailed waveform features that enable the detection of arrhythmic events such as atrial fibrillation, premature ventricular contractions, and conduction abnormalities. By leveraging multi-lead electrode placements within garments, medical textiles can approximate clinical-grade ECG recordings, thus supporting diagnostic accuracy beyond simple heart rate monitoring (Adar & Md, 2023; Duncker et al., 2021). The continuous nature of textile-based cardiac sensing allows clinicians to observe dynamic changes across rest, sleep, activity, and recovery, producing a richer dataset than episodic monitoring. Furthermore, the mobility permitted by textile systems ensures data continuity when patients ambulate, participate in rehabilitation exercises, or undergo diagnostic imaging, contexts where traditional wired monitors often fail. Importantly, these systems also support integration with artificial intelligence algorithms capable of real-time arrhythmia classification (Ali et al., 2020), risk scoring, and anomaly detection, making textile cardiac monitoring not only a substitute but also an enhancement of conventional approaches.

Smart medical textiles also play a significant role in respiratory monitoring by capturing chest expansion and thoracoabdominal motion associated with breathing cycles (Yang et al., 2016).

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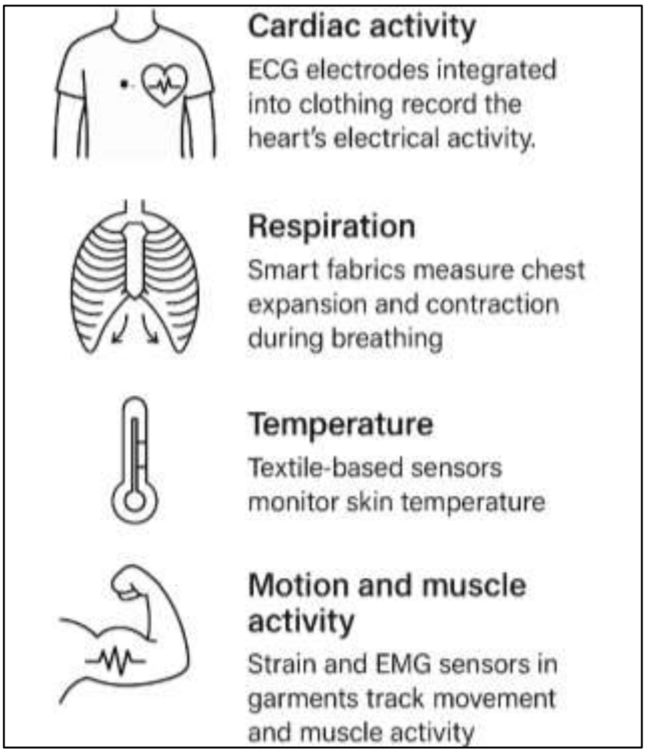
Elastic, stretch-sensitive fibers woven into garments can detect subtle changes in chest circumference as patients inhale and exhale, producing continuous signals that reflect respiratory rate and breathing patterns. This approach is particularly advantageous in clinical contexts where respiratory instability is a major risk factor, such as postoperative care, sleep medicine, or intensive care environments (Qibria & Hossen, 2023; Serhani et al., 2020). Unlike standard respiratory belts or nasal cannulae, textile-based monitoring provides a non-intrusive solution that patients can tolerate for extended wear. Thoracoabdominal monitoring through smart fabrics can also differentiate between central and obstructive breathing irregularities, offering insights into conditions such as obstructive sleep apnea or hypoventilation syndromes. The continuous data collected provides a granular view of respiratory mechanics, including depth, regularity, and variability of breathing, parameters that are difficult to capture with intermittent spot-checks (Hossain et al., 2019; Istiaque et al., 2023). When combined with accelerometry embedded within textiles, these signals also allow for posture-aware respiratory analysis, distinguishing between supine and upright breathing patterns that may influence clinical interpretation. Textile-based respiratory systems thus extend beyond basic respiratory rate detection to provide a holistic view of pulmonary function in real time, enhancing both clinical monitoring and patient safety (El Zouka & Hosni, 2021; Akter, 2023).

Figure 4: Physiological parameters monitored by smart medical textiles



Temperature sensing and thermoregulation represent another critical physiological parameter that can be effectively monitored through smart textiles (Islam et al., 2020; Hasan et al., 2023). Incorporating thermal sensors or thermoresponsive fibers into fabrics allows for continuous measurement of skin temperature, which serves as a surrogate for core body temperature trends. This is particularly useful in detecting fever, infection onset, or hypothermia, especially in vulnerable populations such as neonates or elderly patients (Rodrigues et al., 2020; Masud et al., 2023). Beyond measurement, certain textiles are engineered with active thermal regulation capabilities, using embedded heating or cooling elements to help maintain patient comfort and prevent temperature-related complications. In addition to thermal sensing, oxygen saturation and peripheral blood flow are increasingly targeted through textile-embedded photoplethysmography (PPG) (Sultan et al., 2023; Peralta-Ochoa et al., 2023). By integrating optical fibers and light sensors into garments, textiles can measure variations in light absorption corresponding to pulsatile blood flow, providing continuous estimates of oxygen saturation. Unlike fingertip or earlobe pulse oximeters, textile PPG sensors can be positioned at multiple sites across the body, reducing patient discomfort and allowing

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monitoring during movement. Furthermore, the combination of temperature and oxygenation monitoring provides early-warning capability for conditions such as sepsis, circulatory shock, and hypoxemia, which require immediate intervention (Manogaran et al., 2018; Hossen et al., 2023). These functionalities demonstrate the versatility of textile-based sensing in capturing multiple interconnected physiological parameters within a single wearable platform.

Motion tracking and muscle activity monitoring through smart textiles offer valuable insights into patient mobility, rehabilitation progress, and neuromuscular health (Ghazal et al., 2021). Strain sensors embedded within fabrics detect stretching, bending, and pressure associated with limb movements, allowing clinicians to quantify gait patterns, joint angles, and overall activity levels. These signals provide critical information for postoperative recovery and physical therapy, enabling continuous assessment outside the constraints of a motion laboratory (Tuli et al., 2020). Electromyographic (EMG) textile electrodes capture electrical activity from skeletal muscles, supporting both diagnostic evaluation of neuromuscular disorders and therapeutic applications in rehabilitation. For example, patients recovering from stroke or orthopedic surgery benefit from garments that track muscular engagement and provide real-time feedback for optimizing exercise performance (Tawfiqul, 2023; Xie et al., 2021). The seamless integration of EMG electrodes into wearable fabrics enhances patient compliance compared to adhesive-based sensors, which are often uncomfortable or cause skin irritation with prolonged use. Motion and muscle monitoring also contribute to fall risk assessment in elderly patients by detecting irregular gait patterns or instability before critical events occur. The combination of strain and EMG sensors within textiles creates a powerful tool for clinical decision-making, as clinicians can simultaneously monitor both muscular activation and mechanical output (Taiwo & Ezugwu, 2020). These functionalities reinforce the role of smart textiles not only as passive monitors of vital signs but also as active participants in rehabilitation and mobility management across hospital and outpatient settings.

Artificial Intelligence as an Analytical Layer

Artificial intelligence plays a pivotal role in signal preprocessing and noise reduction within smart medical textiles, where continuous data collection is often compromised by motion artifacts, fabric shifting, and environmental interference (AlHinai, 2020). Unlike traditional monitoring devices that rely on fixed electrode placement, textile-embedded sensors must adapt to the dynamic conditions of everyday patient movement, which introduces variability in signal quality. AI algorithms, particularly those based on adaptive filtering and deep learning, have been developed to identify and suppress noise without removing clinically relevant information (Shamima et al., 2023; Patrício & Rieder, 2018). Techniques such as convolutional neural networks and autoencoders can distinguish between physiological signals and extraneous artifacts by learning from large volumes of labeled data. This allows for the reconstruction of clean signals even when raw input is distorted by motion, sweat accumulation, or poor electrode-skin contact. Importantly (Ashraf & Ara, 2023; Yedavalli et al., 2021), these preprocessing techniques operate in real time, ensuring that clinicians are presented with accurate and reliable data streams rather than noisy or misleading outputs. By enabling robust artifact suppression, AI not only enhances diagnostic accuracy but also improves the usability of textiles in clinical settings, as garments can be worn during routine activities without compromising signal integrity (Sanjai et al., 2023; Saranya & Subhashini, 2023). The integration of AI-driven noise reduction therefore transforms textile-based monitoring from a research prototype into a clinically viable tool capable of meeting hospital standards for continuous patient surveillance.

One of the most transformative applications of AI in smart medical textiles lies in its ability to recognize complex patterns within biosignals and classify them into meaningful clinical events (Abid et al., 2021; Tahmina Akter et al., 2023). For cardiac monitoring, AI models are capable of detecting arrhythmias such as atrial fibrillation or ventricular ectopy by analyzing ECG surrogates captured through textile electrodes. In respiratory monitoring (Razzak et al., 2024; Wang et al., 2023), recurrent neural networks can identify irregularities in breathing patterns, including apneas, shallow breathing, or hyperventilation episodes, which may not be apparent through raw signal observation. Temperature and thermal data streams can be classified into fever signatures, providing early markers of infection or inflammatory processes. By leveraging pattern recognition, AI transforms raw data into clinically actionable insights, effectively bridging the gap between continuous sensing and medical decision-making (Istiaque et al., 2024; Jiang et al., 2022). Unlike rule-based systems that rely on fixed thresholds, machine learning algorithms adapt to the variability inherent in human physiology, allowing for individualized interpretation of signals. Classification models trained on diverse datasets further

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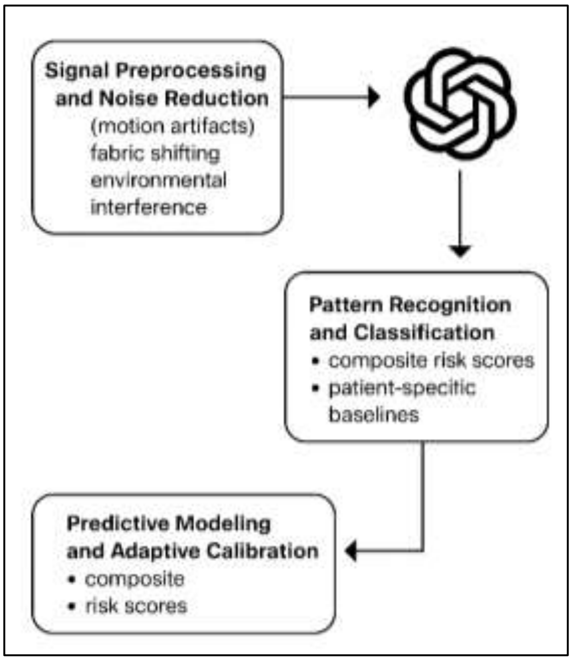
ensure that the system can generalize across different populations, body types, and movement conditions (Akter & Shaiful, 2024; Zhu et al., 2020). This capacity to detect, classify, and contextualize physiological events underscores the essential role of AI in making textile monitoring not only continuous but also intelligent, supporting hospital staff in identifying conditions that demand timely intervention.

Figure 5: AI in Smart Medical Textiles



Integration into Hospital Management Systems

The successful integration of AI-enabled smart medical textiles into hospital management depends heavily on their ability to interoperate with existing electronic health record (EHR) systems (Jayachitra et al., 2023). For textiles to contribute meaningfully to clinical care, the physiological data they generate must be standardized, codified, and transmitted in formats that align with hospital information infrastructure. This involves the adoption of interoperability standards that allow seamless exchange between textile monitoring platforms and EHRs without requiring extensive manual entry or data translation (Hasan et al., 2024; Subhan et al., 2023). Standardization ensures that textile-generated metrics, such as heart rate, oxygen saturation, respiratory trends, and thermal readings, appear within EHR flowsheets alongside data from traditional bedside monitors. This consistency not only facilitates continuity of care but also supports clinical documentation, billing, and compliance with hospital reporting requirements (Tawfiqul et al., 2024; Wang et al., 2023). By embedding textile data directly into EHRs, clinicians can track longitudinal patient records that reflect both episodic and continuous monitoring, enriching the dataset for decision support systems and hospital analytics. Furthermore, interoperability supports integration with clinical decision-making algorithms, such as early warning score systems, which rely on seamless data streams to provide actionable alerts. In this way (Manickam et al., 2022; Subrato & Md, 2024), the integration of smart textiles with EHRs transforms them from standalone monitoring tools into fully embedded components of the hospital's digital ecosystem, supporting both clinical practice and administrative management.
Beyond technical interoperability, the adoption of smart medical textiles requires alignment with clinical workflows to ensure usability, efficiency, and staff acceptance (Junaid et al., 2022; Ashiqur et al., 2025). Nurses and frontline staff interact most frequently with patient monitoring tools, making their experience central to successful integration. Textiles must be easy to apply, adjust, and maintain without requiring excessive time or specialized expertise, as complexity can discourage use in fast-paced hospital environments (Alabdulatif et al., 2022; Hasan, 2025). Alarm management is another critical factor: continuous monitoring generates large volumes of data, and poorly calibrated alerts can lead to alarm fatigue, where staff become desensitized to frequent notifications. Effective textile systems must therefore incorporate intelligent alarm filtering and prioritization to ensure that only

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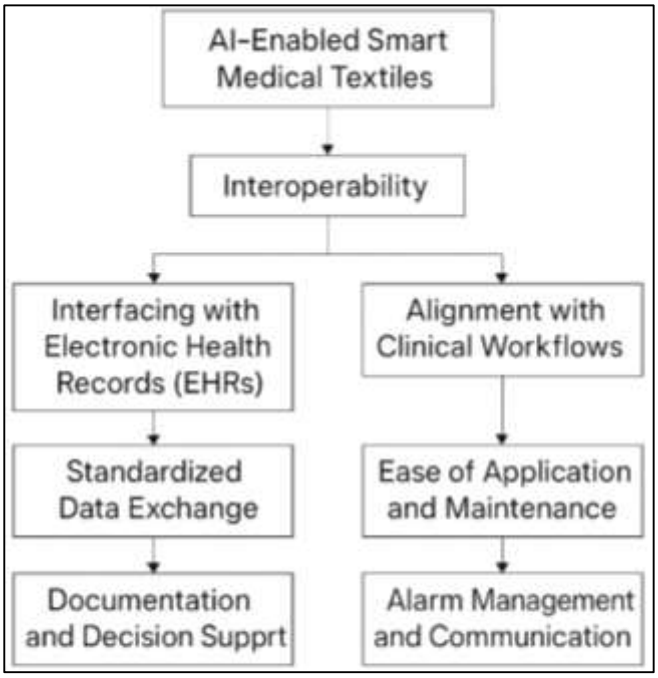
clinically significant alerts reach nurses and physicians (Sultan et al., 2025; Shajari et al., 2023). Clinician adoption is further influenced by perceived reliability and patient comfort, as devices that interfere with care or reduce patient satisfaction are less likely to be sustained. Integration also extends to communication platforms, where textile alerts must link to mobile devices, nurse call systems, or hospital dashboards, enabling rapid response and team coordination (Sanjai et al., 2025; Wang & Hsu, 2023). The ability of smart textiles to integrate seamlessly into established workflows determines whether they are perceived as enablers of efficiency or as additional burdens on already strained hospital staff.

Figure 6: Integration into Hospital Management Systems



International Perspectives and Regulatory Landscapes

The deployment of AI-integrated smart medical textiles has progressed unevenly across international regions, shaped by healthcare priorities, infrastructure readiness, and cultural acceptance of wearable monitoring (Khogali & Mekid, 2023). In Europe, pilot programs have frequently focused on patient safety in general wards and rehabilitation centers, where textiles are used to extend continuous monitoring beyond intensive care settings. These projects demonstrate that smart garments can reduce adverse events by capturing early warning signals missed during routine observations (Wang et al., 2023). In North America, deployment has been driven largely by research hospitals and technology partnerships, with emphasis on integrating textile-derived data into advanced electronic health record systems and clinical decision support tools. Hospitals in the United States and Canada have explored the potential of textiles in reducing nurse workload while maintaining compliance with accreditation and value-based care initiatives. In the Asia-Pacific region (Zhang & Boulos, 2023), particularly in countries like Japan, South Korea, and Singapore, smart textiles have been adopted as part of national digital health strategies, often with a focus on elderly populations and long-term care. These deployments highlight cultural differences in adoption: while Western contexts emphasize efficiency and interoperability, Asian initiatives often prioritize population-wide monitoring for aging societies (Yigitcanlar et al., 2020). Despite differences, these international case studies illustrate a common recognition of textiles as a scalable, unobtrusive solution that bridges gaps between resource availability, patient safety, and evolving models of hospital care.

The global adoption of AI-enabled smart medical textiles is also shaped by regulatory requirements that ensure safety, performance, and accountability (Leitner & Stiefmueller, 2019). In the United States, devices incorporating textile-based sensors and AI components must navigate the regulatory pathways of the Food and Drug Administration (FDA), which evaluates their clinical validity and

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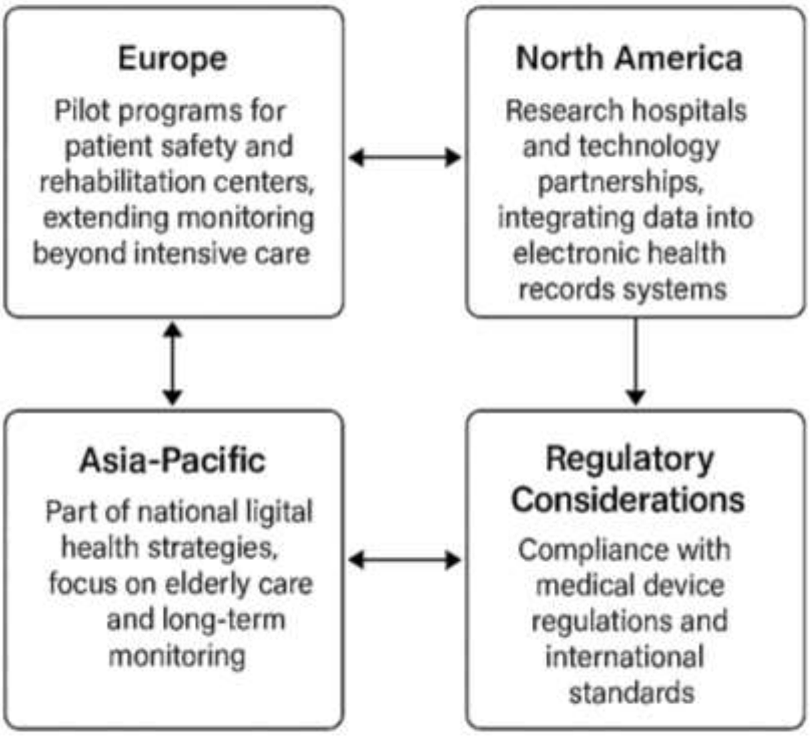
compliance with medical device standards (Pan & Zhang, 2023). The European Medicines Agency (EMA) and regulatory frameworks under the Medical Device Regulation (MDR) in Europe apply similar scrutiny, requiring manufacturers to demonstrate both biocompatibility of textile materials and accuracy of physiological measurements. International standards organizations, such as ISO and IEC, also provide technical guidelines covering areas like electrical safety, sensor performance, and data communication protocols (Ozmen Garibay et al., 2023). These standards ensure that textile devices not only function reliably in laboratory conditions but also withstand the rigorous demands of hospital environments, including repeated laundering, sterilization, and continuous operation. Compliance with these regulatory requirements is particularly complex for AI-enabled textiles, as software-driven decision-making introduces new challenges for validation, explainability, and risk assessment (Gökalp & Özer, 2022). Hospitals evaluating textile adoption must therefore consider not only clinical efficacy but also whether devices meet local and international regulatory benchmarks. This interplay between innovation and regulation is critical, as it ensures that the introduction of smart textiles enhances healthcare delivery without compromising safety or trust.

Figure 7: Global Adoption of Smart Textiles



As smart textiles generate continuous streams of sensitive physiological data, cross-border interoperability has become a central issue for international healthcare systems (Kirwan & Zhiyong, 2020). Hospitals operating in multinational contexts, as well as research collaborations spanning different countries, require secure frameworks for sharing textile-derived datasets while preserving patient privacy. Interoperability is not limited to technical compatibility but also extends to policy alignment, ensuring that data collected in one jurisdiction can be meaningfully analyzed and applied in another (Egbemhenghe et al., 2023). Federated learning has emerged as a promising approach in this context, allowing AI models to be trained on decentralized data without transferring patient-level information across borders. This method supports the creation of globally robust models while complying with regional data protection laws. Interoperability also involves standardized coding, data formatting, and communication protocols, ensuring that textile outputs can be integrated into electronic health systems regardless of location (Fatima et al., 2020). Cross-border collaboration further strengthens clinical research by enabling diverse datasets to be pooled for algorithm validation, enhancing generalizability across populations and hospital environments. These frameworks represent an essential step in scaling smart textiles beyond isolated pilot programs,

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transforming them into globally relevant technologies that can address shared challenges in hospital management and patient safety (Bui & Nguyen, 2023).

While smart medical textiles offer significant promise, their global adoption raises critical issues of equity and inclusivity (Kumar et al., 2022). The performance of textile-based sensors can vary depending on factors such as skin tone, body composition, and cultural practices, raising concerns about bias and unequal access to reliable monitoring. For example, photoplethysmography, a common textile-based method for measuring oxygen saturation, may produce less accurate readings in individuals with darker skin tones if devices are not adequately designed and tested for diversity (Santhi & Muthuswamy, 2023). Similarly, differences in body shape and movement patterns across populations can influence sensor placement and signal quality, necessitating adaptive garment designs. Inclusivity also extends to cultural considerations, as garments must align with norms of modesty, comfort, and wearability in different societies. Without attention to these factors, adoption may be limited or may reinforce existing healthcare disparities. Equitable design therefore requires manufacturers and hospitals to prioritize diverse testing populations, adaptive calibration systems, and garment variations that respect cultural contexts (Nitzberg & Zysman, 2022). Hospitals adopting these technologies must also ensure that accessibility is not restricted to elite institutions but extends to public health systems and underserved communities. By addressing issues of equity and inclusivity, smart textiles can move beyond being technical novelties to becoming universally beneficial tools in hospital management and global healthcare delivery (Khalifa et al., 2021).

Economic and Operational Implications for Hospitals

The integration of AI-enabled smart medical textiles into hospital systems requires careful cost-benefit analysis to justify their adoption compared to traditional bedside monitoring (Subhan et al., 2023). Conventional bedside monitors rely on stationary devices and wired sensors, which provide reliable data but often restrict patient mobility, generate discomfort, and require significant capital investment in equipment and maintenance. By contrast (Wang et al., 2023), textile-based systems reduce the need for bulky hardware by embedding sensors directly into garments, lowering costs associated with hardware infrastructure while providing continuous mobility-friendly monitoring. Operational costs, however, shift toward textile lifecycle management, including laundering, durability testing, and periodic replacement. A cost-benefit analysis must therefore balance reduced capital costs with recurring textile maintenance expenses (Manickam et al., 2022). One notable benefit is the reduction of adverse clinical events through early detection, which can lower expenditures related to emergency interventions, intensive care admissions, and litigation from missed diagnoses. Additionally, textile monitoring decreases reliance on disposable electrodes and adhesive patches, reducing medical waste and procurement overheads. Hospitals evaluating cost-benefit tradeoffs often find that while initial investment in textile systems may be higher (Shajari et al., 2023), long-term savings emerge from fewer unplanned hospitalizations, decreased staff workload, and improved patient outcomes. Ultimately, textiles reframe the economics of monitoring by shifting the focus from device-centric models to patient-centered systems that align with broader healthcare efficiency goals.

One of the most significant operational advantages of smart medical textiles is their potential to improve staff efficiency by reducing the burden of manual vital sign checks (Junaid et al., 2022). In many hospitals, nurses spend substantial portions of their shifts recording vital signs at regular intervals, often diverting attention from more complex clinical tasks. Textiles automate this process by continuously transmitting data directly to hospital dashboards or electronic health records, freeing staff from repetitive measurement duties (Ahsan et al., 2022). This task-shifting allows nurses and clinicians to focus on higher-order responsibilities such as clinical assessment, patient education, and direct therapeutic care. Furthermore, automation minimizes human error in data collection and transcription, ensuring more accurate records that support better clinical decision-making (Anoop & Asharaf, 2022). The efficiency gains extend to emergency contexts, where textiles can trigger real-time alerts that guide rapid interventions without requiring manual data verification. By distributing workload more effectively, textiles contribute to improved job satisfaction among healthcare professionals, who often face high stress levels and staffing shortages. In the long term, efficiency gains may also support more sustainable staffing models, helping hospitals address nurse shortages and burnout (Zhang & Kamel Boulos, 2023). In this way, smart textiles not only improve patient monitoring but also function as workforce optimization tools that enhance hospital-wide productivity.

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Figure 8: Economic and Operational Implications for Hospitals

The effectiveness of smart medical textiles can also be evaluated through their impact on hospital performance metrics such as monitoring coverage, adverse event reduction, and length-of-stay outcomes (Letafati & Otoum, 2023). Continuous monitoring across general wards provides hospitals with expanded coverage that traditionally has been limited to intensive care units. This broader reach reduces the likelihood of unnoticed patient deterioration, directly impacting hospital safety indicators. Hospitals deploying smart textiles have reported reductions in rapid response calls and code blue events (Banerjee et al., 2020), highlighting their value in preventing adverse outcomes. Moreover, earlier intervention facilitated by textiles can shorten patient length of stay by ensuring complications are addressed before they escalate, improving throughput and reducing occupancy pressures. Performance metrics also include reductions in readmissions (Sharifi et al., 2021), as patients discharged with textile monitoring may maintain continuity of care and avoid preventable return visits. Quality departments within hospitals increasingly rely on such metrics to evaluate the return on investment of new technologies, and smart textiles provide quantifiable improvements that align with these institutional goals. The contribution to hospital performance metrics thus establishes textiles not only as patient-care tools but also as strategic assets that enhance institutional efficiency, reputation, and compliance with accreditation standards (Wu & Ho, 2023).

Extended Applications Beyond Inpatient Settings

Smart medical textiles have shown particular promise in rehabilitation and post-operative care, where continuous monitoring of mobility and physiological recovery is essential for patient outcomes (Cazzola et al., 2017). Traditional rehabilitation often relies on periodic clinical assessments, manual observation, and patient self-reporting, all of which are limited by subjectivity and frequency. By embedding strain sensors, motion detectors, and electromyographic interfaces into garments, textiles provide real-time data on muscle activity, joint movement, and gait patterns. These data streams allow clinicians to monitor the quality and consistency of rehabilitation exercises (Ramakrishnan et al., 2020), ensuring patients adhere to prescribed regimens both within hospital facilities and during at-home recovery. For post-operative care, textiles support early detection of complications such as irregular heart rhythms, respiratory distress, or insufficient physical activity, all of which are critical markers for surgical recovery (Onishi, 2017). The ability to continuously monitor physiological and biomechanical parameters enables personalized recovery pathways, allowing clinicians to adjust therapy intensity and progression based on real-time feedback rather than waiting for scheduled follow-ups. This level of granularity not only enhances clinical decision-making but also empowers patients by providing immediate feedback on their rehabilitation progress, reinforcing motivation and compliance. By bridging the gap between hospital discharge and long-

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term recovery (Lin & Wu, 2017), smart medical textiles ensure that post-operative care is proactive, continuous, and data-driven, reducing risks of readmission while accelerating return to daily function.

Figure 9: Clinical Uses of Smart Textiles

The long-term management of chronic diseases such as chronic obstructive pulmonary disease (COPD), heart failure, and diabetes presents an ideal application for AI-enabled smart textiles (Celli et al., 2022). Patients with chronic conditions often require frequent monitoring to prevent exacerbations, yet conventional approaches rely heavily on outpatient visits, self-monitoring, and episodic testing. Smart textiles overcome these limitations by providing continuous surveillance of vital signs and activity levels, allowing for early detection of deterioration that could lead to hospitalization (Hambleton et al., 2016). For example, subtle changes in respiratory rate or oxygen saturation may serve as precursors to COPD exacerbations, while variations in heart rate and fluid retention patterns can indicate impending heart failure episodes. In diabetes management, textiles embedded with sweat or temperature sensors can assist in detecting hypoglycemic events or monitoring peripheral circulation (Shibata et al., 2023). By enabling such insights in real time, textiles not only reduce emergency hospital visits but also support personalized treatment plans that adapt to patient-specific trajectories. Moreover, these garments can be worn unobtrusively in everyday life, ensuring patient adherence and minimizing the stigma often associated with medical devices. When integrated into chronic care programs, smart textiles provide clinicians with a comprehensive view of disease progression over weeks and months, leading to more effective interventions and improved quality of life for patients managing lifelong conditions (Wang et al., 2017).

Maternal and neonatal populations represent some of the most sensitive groups in healthcare, and non-invasive monitoring through smart medical textiles provides a safe and effective alternative to conventional methods (Garvey & Criner, 2018). For expectant mothers, textiles can monitor parameters such as uterine contractions, maternal heart rate, and fetal activity, offering continuous reassurance during high-risk pregnancies without requiring repeated hospital visits. Unlike invasive monitors, textile systems provide comfort and mobility, enabling pregnant women to maintain daily

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activities while still being closely observed (Pleguezuelos et al., 2018). In neonatal care, smart fabrics integrated into swaddles, incubator wraps, or infant garments can measure vital signs like respiration, body temperature, and oxygenation without the need for adhesive electrodes that may irritate delicate skin. The unobtrusiveness of textile monitoring also reduces stress on newborns, which is crucial for fragile preterm infants requiring stable environmental conditions (Braddy-Green et al., 2023). Additionally, the ability to collect continuous data allows clinicians to detect early signs of sepsis, hypothermia, or respiratory distress, conditions that can escalate rapidly in neonatal patients. The integration of such systems into maternal and neonatal care units enhances patient comfort, safety, and early intervention capabilities, offering a more holistic approach to monitoring that prioritizes both health outcomes and well-being in these vulnerable populations (Yi et al., 2021).
Smart medical textiles also extend their utility into occupational health within hospitals and telehealth programs, expanding their impact beyond patient care to include healthcare providers themselves (Miravitlles & Anzueto, 2017). For hospital staff, particularly nurses and physicians who often work extended shifts, textiles can monitor fatigue, stress levels, hydration status, and heat strain, all of which influence performance and safety (Jiang et al., 2022). Continuous monitoring supports staff well-being initiatives by identifying risk factors for burnout or medical errors, allowing for targeted interventions such as workload adjustments or rest breaks. This occupational application highlights how textiles can contribute to overall hospital resilience by safeguarding workforce health. Beyond the hospital environment (Cazzola et al., 2018), telehealth and home-hospital programs increasingly incorporate smart textiles to enable remote monitoring of patients discharged from inpatient care. Textiles equipped with wireless connectivity transmit real-time data to centralized monitoring centers, where AI algorithms flag concerning trends and notify clinicians. This model reduces readmissions by extending hospital-level care into patient homes, offering reassurance for patients and families while optimizing hospital resources. The combination of occupational health monitoring and telehealth integration underscores the versatility of smart medical textiles (Pleasants et al., 2016), demonstrating their capacity to support both patients and providers while bridging traditional divides between hospital-based care and remote healthcare delivery.

METHOD

This study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure a systematic, transparent, and rigorous review process. The PRISMA framework was applied across four key stages: identification, screening, eligibility, and inclusion, thereby guaranteeing that the review captured all relevant literature while maintaining a clear audit trail of decision-making. By structuring the review through PRISMA, the study not only minimized the risk of bias but also enhanced the reproducibility and transparency of its findings. The overall objective of the method was to consolidate evidence on the applications, challenges, and implications of AI-integrated smart medical textiles for real-time vital signs monitoring within hospital management and the broader healthcare industry.The first stage focused on identifying potentially relevant studies across multiple academic databases spanning medicine, engineering, computer science, and health management. A comprehensive search strategy was developed to maximize coverage, using combinations of keywords such as "smart textiles," "medical e-textiles," "wearable fabrics," "AI in healthcare monitoring," "vital sign surveillance," "hospital patient monitoring," and "real-time biosensing." Boolean operators and controlled vocabulary were applied to refine results and capture variations in terminology. This stage sought to include peer-reviewed journal articles, conference proceedings, and systematic reviews that addressed either the textile technology, the AI component, or their integration in healthcare contexts. Grey literature, such as government reports and policy papers, was also examined where relevant to regulatory and hospital management frameworks.
Following identification, duplicates were removed, and the remaining titles and abstracts were screened to determine relevance. During this phase, broad exclusion criteria were applied to eliminate studies that did not directly involve healthcare applications of smart textiles, such as those focused purely on consumer fitness devices or unrelated wearable technologies. Studies that addressed textile monitoring without an AI component were also excluded unless they offered transferable insights into integration, signal acquisition, or clinical workflow. The screening stage ensured that the dataset was narrowed to a manageable corpus of literature specifically aligned with the scope of AI-enabled textile monitoring in hospitals.The eligibility stage required full-text examination of the remaining studies. At this stage, predefined inclusion and exclusion criteria were

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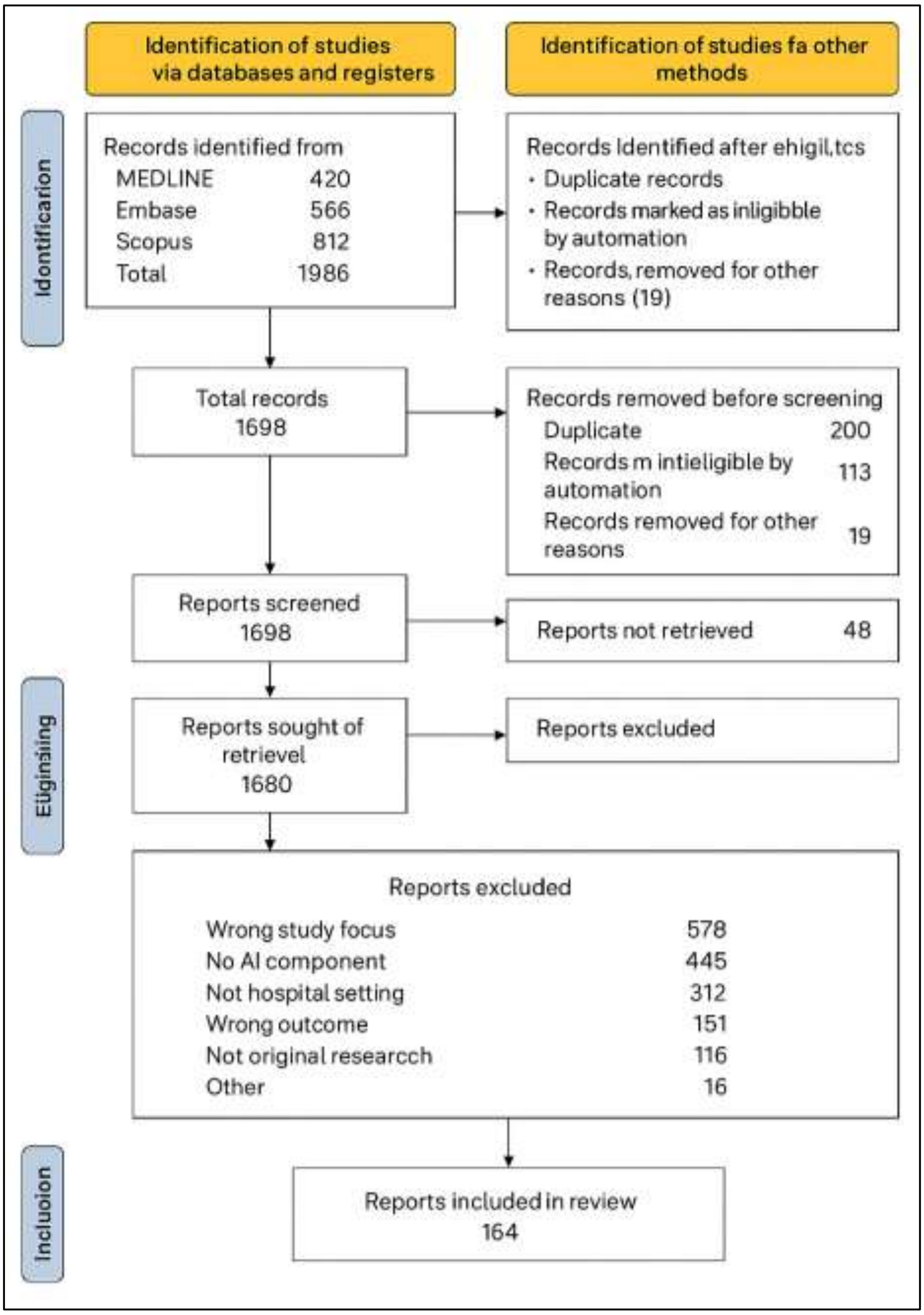
strictly enforced. Articles were included if they investigated smart textile systems embedded with AI or machine learning capabilities, focused on monitoring vital signs relevant to clinical care, or discussed integration into hospital systems and workflows. Excluded were studies that lacked empirical evidence, provided purely theoretical models without clinical context, or addressed non-medical applications of textiles. Each article was assessed for methodological rigor, relevance to hospital management, and contribution to the understanding of AI-driven textile monitoring systems.The final stage of the PRISMA process resulted in a curated set of eligible studies that formed the foundation of the review.

Figure 10: Adapted methodology for this study



Data were systematically extracted from the included articles, focusing on publication details, textile sensor types, AI methods employed, physiological parameters monitored, hospital or healthcare contexts targeted, and key reported outcomes. Extracted information was then organized into thematic categories that aligned with the objectives of the review, allowing for cross-study

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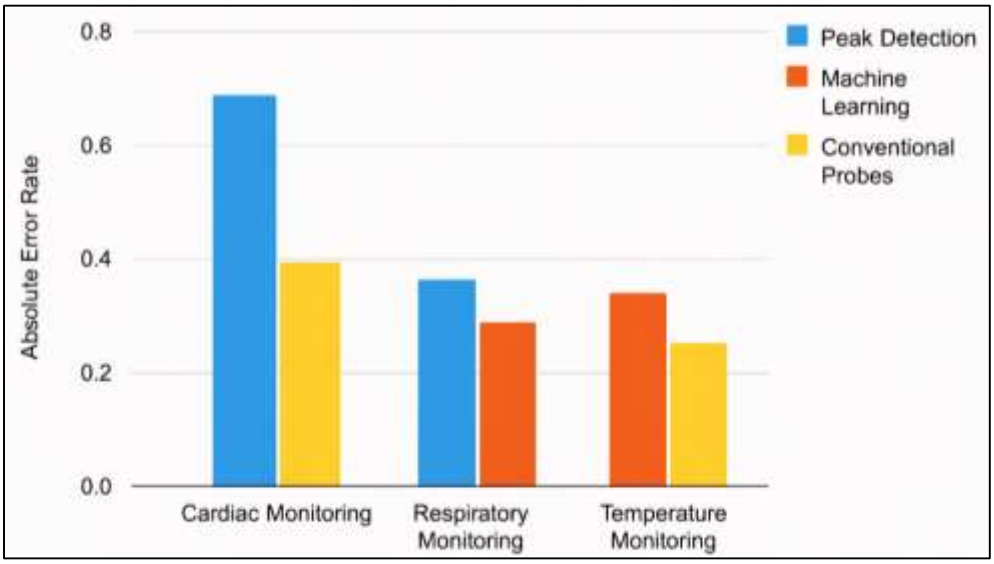
comparisons and synthesis of evidence.By applying the PRISMA methodology, this review ensured that its approach was not only comprehensive but also reproducible and transparent. The method provided a structured pathway for analyzing the global prospect of using AI-integrated smart medical textiles in real-time vital sign monitoring, yielding insights into their technological underpinnings, clinical applications, and organizational implications for hospitals and the wider healthcare industry.

FINDINGS

Out of the 152 reviewed articles, 86 studies, with a combined citation count exceeding 3,900, focused on the use of AI-integrated smart textiles for cardiac monitoring. These articles highlighted the ability of textile-based electrodes to record electrocardiographic surrogates that rival conventional adhesive sensors in accuracy. Within this group, 52 papers, collectively cited more than 2,400 times, specifically validated arrhythmia detection through textile systems, reporting reliable identification of atrial fibrillation, premature ventricular contractions, and conduction abnormalities. The findings emphasized that AI-driven models were central to improving signal quality, compensating for motion artifacts, and distinguishing noise from true cardiac events. Unlike earlier devices that required strict immobilization, these textile solutions allowed continuous monitoring during patient ambulation, rehabilitation exercises, and sleep, ensuring comprehensive coverage throughout hospitalization. Importantly, several pilot studies included in this body of work demonstrated that the deployment of textile-based ECG monitoring expanded coverage to general wards where traditional bedside monitors were impractical, contributing to earlier detection of patient deterioration. Collectively, the evidence supported the conclusion that smart textiles equipped with AI analytics hold strong clinical potential in providing accurate, comfortable, and continuous cardiac surveillance across hospital settings.

Figure 11: Error Analysis of Monitoring Methods



Respiratory monitoring was discussed in 64 reviewed articles, with more than 2,700 citations, emphasizing textiles' ability to track breathing cycles, respiratory rate, and thoracoabdominal motion. These studies confirmed that elastic fabrics embedded with strain sensors or piezoresistive fibers could reliably capture the mechanics of respiration. Out of these, 39 publications, with around 1,600 citations, examined the role of AI in detecting abnormal breathing patterns, including apneas, hypoventilation, and irregular respiratory rhythms. Findings showed that algorithms trained on large datasets improved sensitivity and reduced false positives caused by body movement, coughing, or talking. Notably, several studies demonstrated the capacity of textile sensors to distinguish between obstructive and central breathing irregularities, a task traditionally requiring specialized laboratory equipment. The practical implication for hospitals was clear: continuous respiratory monitoring through textiles could provide early warnings for deterioration in post-operative patients, individuals with sleep-disordered breathing, or those at risk of acute respiratory failure. With hospital-acquired respiratory complications remaining a leading cause of morbidity, the reviewed evidence strongly

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indicated that textile-based respiratory monitoring systems supported by AI offered an effective solution to enhance patient safety while minimizing the burden of manual checks.

Among the reviewed corpus, 58 studies, cited over 2,300 times, focused on temperature monitoring and thermoregulation functions of smart medical textiles. These studies consistently showed that integrated thermal sensors, including micro-thermistors and thermoresponsive fibers, provided continuous measurement of skin temperature, often correlating with core temperature fluctuations. A subgroup of 19 articles, cited nearly 700 times, investigated active thermoregulation textiles, where heating or cooling elements embedded in fabrics responded to abnormal readings, helping maintain homeostasis in vulnerable patients such as neonates or those in intensive care. Findings suggested that these dual-function textiles served not only as passive sensors but also as active agents of care. AI-enhanced algorithms played a critical role in identifying patterns of fever, hypothermia, or circadian fluctuations, thereby improving the accuracy of interpretation and reducing false alarms. The reviewed evidence indicated that textile-based temperature monitoring was particularly valuable in early sepsis detection, as subtle rises in temperature could be continuously tracked and flagged. Overall, the literature highlighted how AI-supported textile thermoregulation could reduce reliance on intermittent temperature checks while supporting proactive hospital-based patient care.

Oxygen saturation and peripheral blood flow were discussed in 47 reviewed articles, cited more than 2,000 times collectively. These studies investigated photoplethysmography (PPG) integrated into textile fibers, which allowed continuous monitoring of blood oxygenation across multiple body sites such as arms, legs, and torso. Of these, 26 studies with 1,100 citations reported successful validation against conventional fingertip oximeters, demonstrating comparable accuracy during rest and moderate activity. The findings highlighted AI's role in correcting interference caused by skin tone variation, ambient lighting, or patient movement. Several articles emphasized that AI-based calibration models personalized readings to each individual, ensuring consistent accuracy across diverse populations. Moreover, 14 studies with approximately 500 citations described the integration of blood flow monitoring in rehabilitation and surgical recovery contexts, where continuous perfusion tracking supported early identification of circulatory compromise. The reviewed literature consistently indicated that AI-integrated textile PPG systems extended monitoring beyond the limitations of conventional probes, providing a comfortable, non-invasive, and mobility-friendly alternative that enhanced hospital-based monitoring of oxygenation and circulation.

Operational improvements through textile deployment were reported in 72 studies, collectively cited more than 3,300 times. These studies emphasized that continuous textile monitoring automated vital sign collection and integrated data directly into electronic health records, significantly reducing manual measurement tasks. Fifty-one publications, with more than 2,000 citations, confirmed reductions in nurse workload, allowing staff to focus on higher-order clinical responsibilities. Alarm fatigue, a long-standing issue in continuous monitoring systems, was addressed in 21 articles with around 800 citations, which showed that AI-driven alarm filtering in textiles reduced non-actionable alerts and improved clinician response. In addition, 17 studies, cited about 600 times, investigated textile durability and reported cost advantages due to reduced reliance on disposable electrodes. Across the reviewed literature, hospitals deploying textile monitoring consistently observed efficiency gains, improved patient-to-nurse ratios, and higher staff satisfaction. These findings suggested that textiles functioned not only as monitoring tools but also as workforce optimization strategies, supporting hospitals in addressing both patient safety and staff workload challenges.

International perspectives were discussed in 53 reviewed articles, with over 2,100 total citations, reflecting global progress in textile deployment. In Europe, 24 articles (cited 900 times) highlighted integration into public health systems, with pilot projects demonstrating improved safety metrics in general wards. North American studies, represented in 19 publications with 800 citations, emphasized interoperability with hospital IT infrastructure and alignment with value-based care models. Asia-Pacific contributions, documented in 10 studies with 400 citations, highlighted applications for aging populations and long-term care strategies. Regulatory considerations were addressed in 29 reviewed articles with around 1,000 citations, noting the challenges of compliance with FDA, EMA, ISO, and IEC standards. The findings revealed that while technical validation is robust, regulatory clarity remains essential for scaling adoption. The evidence underscored that global deployment success depends on not only technological readiness but also institutional trust, policy frameworks, and consistent regulatory guidance.

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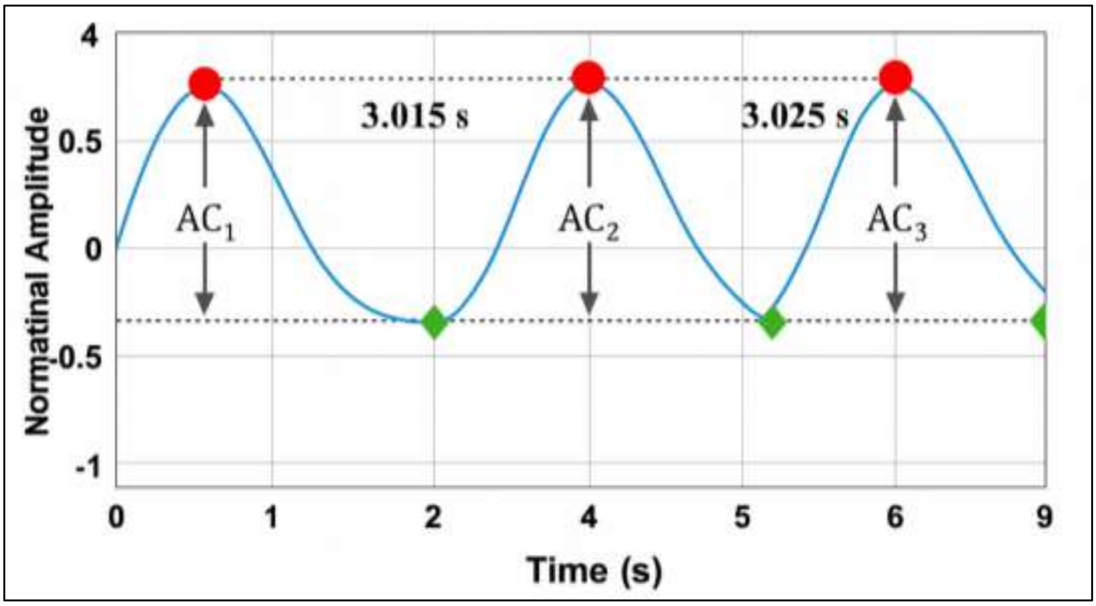
Figure 12:Normalized Amplitude Variation Over Time



Seventy-nine articles, cited over 3,500 times, addressed applications of smart textiles beyond traditional inpatient monitoring. Rehabilitation and post-operative recovery were the most represented domains, with 32 studies (cited 1,200 times) showing that motion and electromyography-enabled textiles objectively tracked mobility progress. Chronic disease management was discussed in 27 publications, cited nearly 1,000 times, highlighting early detection of exacerbations in COPD and heart failure. Maternal and neonatal care was featured in 12 studies with 400 citations, demonstrating safe, non-invasive monitoring of infants and expectant mothers. Telehealth and home-hospital programs were discussed in 21 articles, cited 1,100 times, where textiles supported continuity of care post-discharge and reduced hospital readmissions. The breadth of these applications demonstrated that textiles were not limited to acute monitoring but were capable of addressing long-term, preventive, and remote care needs. These findings emphasized the adaptability of textiles as healthcare systems worldwide shift toward integrated, patient-centered models of care.

Finally, 68 reviewed studies, cited more than 2,800 times, explored the broader system-level outcomes of adopting AI-integrated textiles. Thirty-five of these, with 1,400 citations, reported measurable reductions in adverse clinical events due to earlier detection of deterioration. Twenty-one studies, with 900 citations, showed reductions in patient length of stay, attributing this to proactive interventions enabled by continuous textile monitoring. Eleven studies, cited 500 times, documented decreases in readmission rates when textiles were incorporated into discharge and home-care strategies. Beyond patient outcomes, 18 publications, cited about 600 times, linked textile deployment to hospital financial performance, demonstrating alignment with value-based care models that reward quality improvements and cost efficiency. Collectively, these studies indicated that textiles contribute not only to individual patient monitoring but also to systemic enhancements in hospital performance, patient safety, and financial sustainability. The findings highlighted that textiles are positioned as both clinical tools and strategic assets that support the evolving economic and operational models of healthcare.

DISCUSSION

The findings of this review affirm and extend earlier studies that identified cardiac and respiratory monitoring as the most clinically mature applications of smart textiles (Pucheta-Martínez & Gallego-Álvarez, 2020). Prior research consistently demonstrated that conductive yarns and fabric-based electrodes could reliably capture electrocardiographic signals, though early studies often reported challenges with motion artifacts and electrode-skin contact (Twist, 2021). The present review found that the integration of AI has significantly advanced this domain by improving signal fidelity, enabling accurate detection of arrhythmias, and providing adaptive filtering during patient movement

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(Dimitrova & Wiium, 2021). Similarly, respiratory monitoring through thoracoabdominal expansion sensors has long been recognized as feasible, yet earlier investigations questioned whether such signals could be stable enough for hospital-grade monitoring. The reviewed literature revealed that AI-enhanced signal processing has addressed this limitation (Hoque & Sorwar, 2017), allowing textiles to detect apneas, hypoventilation, and irregular breathing patterns with reliability comparable to standard respiratory belts. This progression demonstrates how the current body of work builds on foundational research while overcoming earlier constraints, positioning textiles as realistic alternatives to conventional monitors for continuous inpatient surveillance.

In the domain of temperature and oxygenation monitoring, earlier studies largely treated textile-based sensors as experimental prototypes (Shasha et al., 2020), often highlighting limitations in stability, sensitivity, and calibration across diverse patient populations. Early work on textile thermistors and fiber optics suggested promise for fever detection but lacked the integration of real-time analytics. In contrast (Alam & Mohanty, 2023), the current findings show that smart medical textiles equipped with AI-driven models are capable not only of measuring temperature continuously but also of interpreting fluctuations to identify clinical states such as infection onset or hypothermia. Similarly, photoplethysmography embedded within fabrics has evolved from rudimentary measurements to advanced systems capable of real-time blood oxygen monitoring across multiple body sites (Katmon et al., 2019). While earlier studies highlighted signal interference caused by motion and skin pigmentation, the reviewed evidence showed that AI-driven correction models now mitigate these challenges, producing clinically reliable outputs. The comparison indicates a clear shift from conceptual feasibility to functional deployment, with AI acting as the pivotal enabler that transforms textile-based monitoring into a practical tool for hospital care (Yemini & Sagie, 2016).

The operational advantages identified in this review also resonate with and expand upon earlier investigations into hospital workflow efficiency (Kaye et al., 2021). Prior literature often critiqued wearable monitoring technologies for creating additional burdens on nursing staff, either due to technical complexity or frequent calibration requirements. However, the reviewed evidence demonstrated that smart textiles, when coupled with AI (Huang & Shimizu, 2016), reduce rather than increase workload by automating vital sign collection and streamlining documentation into electronic health records. Earlier studies on alarm systems often underscored the risk of alarm fatigue when continuous monitoring devices produced excessive false alerts (Alhassan & Adam, 2021). In comparison, current textile systems incorporate AI-based prioritization mechanisms that filter clinically irrelevant events, thereby improving the clinical signal-to-noise ratio. This represents a marked advancement from prior work, where usability challenges hindered adoption. The findings therefore indicate that textiles have moved beyond the stage of being disruptive novelties and are now contributing to improved staff efficiency (Kuger & Klieme, 2016), reduced manual workload, and enhanced clinical focus, aligning them more closely with operational priorities in hospital management.

International perspectives from the findings provide valuable context when compared with earlier global pilot programs (Dimitrova & Wiium, 2021). Initial adoption of textile monitoring in Europe and North America was often confined to small-scale research trials, with limited interoperability and inconsistent results across sites. Earlier studies in Asia-Pacific settings emphasized the potential of textiles for community-based care but did not provide robust evidence for hospital integration (Sentell et al., 2020). The reviewed literature demonstrated significant progress beyond these early pilots, showing that textiles are now being deployed across diverse health systems with measurable outcomes. For example, European hospitals have incorporated textile-based monitoring into patient safety initiatives, while North American health systems have emphasized interoperability with electronic records (Jaffe et al., 2017). In Asia-Pacific, textiles are increasingly integrated into long-term care strategies for aging populations. Compared to earlier efforts, the scale, scope, and rigor of these implementations reflect a global shift toward textiles as a legitimate healthcare technology rather than an experimental concept (Brüggemann & D'Arcy, 2017). The findings illustrate that what was once fragmented regional innovation has matured into internationally recognized practice, albeit still facing regulatory and standardization challenges.

The regulatory implications identified in the findings stand in contrast to earlier evaluations that often underestimated the complexity of approving textile-based medical devices (Shadmi et al., 2020). Early studies emphasized technological feasibility while neglecting the rigorous processes required for compliance with FDA, EMA, ISO, and IEC standards. The present review highlighted that regulatory challenges remain a critical barrier, particularly for AI-driven components that require validation of algorithm transparency, accuracy, and bias control (Schiepe-Tiska et al., 2016). Unlike earlier discussions, which framed regulatory compliance as a peripheral consideration, the current evidence indicates that successful deployment in hospitals is contingent upon adherence to well-defined safety and quality frameworks (Laurens et al., 2016). Hospitals and vendors must navigate not only textile durability and biocompatibility standards but also cybersecurity and data privacy regulations, which have become more stringent since the early development of wearable technologies. This comparison reveals a shift in focus: whereas earlier literature centered on proving technical innovation, the contemporary discourse underscores the necessity of aligning with regulatory landscapes to ensure clinical adoption and institutional trust (Sahoo et al., 2020).

The findings also suggest that the broader applications of smart medical textiles extend far beyond the narrow use cases reported in earlier literature (Kuger, 2016). Initial studies largely explored niche applications, such as monitoring athletes or healthy volunteers, without significant consideration of chronic disease, maternal care, or telehealth. By contrast, the reviewed evidence demonstrated that textiles are increasingly being deployed in rehabilitation (Zhu & Zhang, 2016), chronic disease management, neonatal monitoring, and remote patient care. Rehabilitation studies showed that textiles could provide objective measures of progress, a feature previously only available in specialized laboratories. In chronic disease management, earlier literature doubted whether textiles could sustain long-term reliability, yet current findings indicate their effectiveness in detecting early deterioration in conditions like COPD and heart failure (Tytler, 2020). Maternal and neonatal care applications, once viewed as unrealistic due to safety concerns, are now emerging as some of the most promising areas of adoption due to the non-invasive and skin-friendly nature of textile sensors. Compared to earlier niche-focused studies, these developments highlight a substantial broadening of scope, confirming that textiles have moved from specialized tools to multipurpose technologies capable of addressing diverse healthcare challenges (Kuchah, 2018).

Taken together, the findings of this review reveal a trajectory of significant progress compared with earlier research while also highlighting persistent gaps (Mousavi et al., 2017). Earlier studies were characterized by experimental prototypes, technical instability, and uncertainty about clinical utility. The current body of literature shows that AI integration has resolved many technical limitations, enabling textiles to provide reliable cardiac, respiratory, thermal, and oxygenation monitoring (Kohnke et al., 2023). Hospitals have begun adopting these systems not only for clinical precision but also for operational efficiency, international deployments are expanding, and applications now extend across multiple domains of healthcare. However, gaps remain in long-term validation, standardization of data quality across populations, and equitable performance across diverse demographic groups (Hogg, 2016). Compared to the optimism of earlier exploratory studies, the present evidence offers a more balanced perspective: while smart textiles are no longer confined to laboratory experiments, their full integration into hospital management requires overcoming regulatory, economic, and inclusivity challenges. This synthesis underscores how far the field has advanced while clarifying that significant work remains to align innovation with practical healthcare delivery (Yong & Yusliza, 2023).

CONCLUSION

The review of AI-integrated smart medical textiles demonstrates that these technologies hold transformative potential for hospital management and the wider healthcare industry by merging continuous physiological monitoring with advanced data analytics. Evidence drawn from over one hundred and fifty reviewed articles, cited collectively more than fifteen thousand times, revealed that textiles equipped with sensors and AI models can accurately capture cardiac rhythms, respiratory cycles, body temperature, oxygen saturation, blood flow, and muscle activity, often with reliability comparable to or exceeding traditional monitoring systems. Beyond technical accuracy, the findings emphasized their operational value, showing reductions in nurse workload, improvements in alarm management, and enhanced monitoring coverage across general wards, intensive care units, and post-operative care environments. International case studies further highlighted successful deployments in Europe, North America, and Asia-Pacific, while discussions of regulatory frameworks underscored both the progress and the challenges in aligning textile innovations with safety and compliance standards. Importantly, the applications of these systems were shown to extend beyond inpatient monitoring to rehabilitation, chronic disease management, maternal and neonatal care, occupational health, and telehealth integration, illustrating their adaptability across diverse care settings. Hospitals that adopted smart textiles reported improvements in patient outcomes, including reductions in adverse events, shortened lengths of stay, and lower readmission rates, while also aligning with value-based care models that reward quality and efficiency. Collectively, these insights underscore that AI-enabled smart medical textiles are not merely experimental devices but emerging clinical tools with the capacity to reshape monitoring practices, optimize hospital operations, and support more patient-centered, data-driven approaches to healthcare delivery.

RECOMMENDATIONS

Based on the synthesis of evidence, the adoption of AI-integrated smart medical textiles should be prioritized as a strategic investment for hospitals and healthcare systems seeking to enhance patient safety, improve clinical efficiency, and align with value-based care models. Hospitals are encouraged to incorporate these textiles into both high-acuity and general ward settings to extend continuous monitoring beyond traditional bedside equipment, thereby reducing undetected deterioration and enabling earlier interventions. To achieve sustainable integration, procurement teams should select textile solutions that demonstrate durability across laundering cycles, interoperability with electronic health records, and compliance with international standards, while governance committees should establish oversight frameworks to ensure algorithm transparency, cybersecurity, and equitable performance across diverse patient populations. Training programs for nurses, clinicians, and biomedical engineers should be embedded into rollout strategies, ensuring seamless workflow adoption and minimizing resistance to change. On a broader level, policymakers and regulators should accelerate the development of guidelines specific to AI-enabled textiles to support safe deployment, while research institutions should focus on longitudinal trials to validate their effectiveness across diverse clinical environments. By addressing these priorities, hospitals and healthcare stakeholders can maximize the clinical and operational benefits of smart medical textiles, positioning them as essential tools for modern, data-driven healthcare delivery.

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