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Emerging Wearable Sensor Technologies for Personalized Health Monitoring and Disease Detection: A Review

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Abstract
Wearable sensor technology improves one's health, wellness, lifestyle, and monitoring performance by allowing continuous, non-invasive calculation of biochemical and biophysical signals from the patient's body. Devices like these are progressively used for personal health monitoring and early disease detection. This review paper deals with the current limitations and gaps of the wearable sensor devices operated in medical field. A lot of studies revealed that recent innovations have improved wearable sensors through multipurpose electronics that facilitate continuous tracking of physiological signals such as heart rate, biochemical markers, and ECGs. However, challenges and limitations still remain in real-world reliability, user comfort, data accuracy and privacy, and standardization. It's important to assess and address gaps in this technology to fully realize its potential in healthcare systems.

***Index Terms*—**Wearable sensor technology, Personalized health monitoring, Disease Detection

I. Introduction

A wearable sensor technology has changed rapidly from using it in just basic fitness trackers to advanced platforms that could monitor physiological and biochemical signals constantly in real time. According to (Adeghe et al., 2024), wearable technologies are now shaping and changing how healthcare is being addressed as patients are monitored all the time, even outside of a traditional healthcare practice. By timely intervention and remote assessment, it could lead to health outcomes better than the traditional clinical setting. These technologies user small sensors, modules with wireless communication, and mobile computing platforms so that it could quickly gather and send data of the patient's health.

Linh et al., 2025, stated that wearable sensors have a lot of functionality including mobile connectivity, delivering autonomous, self-contained operations as it has integrated analytical platforms that combine a set of different features. These are tiny, low-weight, and flexible technology devices that have developed as useful tools for monitoring different physiological, biochemical, and environmental factors straight from the patient's body (As cited in Kurul et al., 2025). This technology has quickly advanced and dramatically transformed the landscape of digital health, personalized medicine, and biomedical engineering (Bakri et al., 2024, as cited in Kurul et al., 2025).

Data collected by wearable sensors are analyzed by using machine learning (ML) and AI algorithms to give findings into a patient's health status, this enable early detection of issues in regards to health and provision of personalized healthcare (Yu et al., 2018, Briganti et al., 2020, as cited in Shajari et al., 2023). These wearable sensors can also motivate and encourage patients healthy living and behavior by providing reminders, incentives, and feedbacks to them, like telling them to exercise, stay active, be hydrated, eat healthy foods, and maintain a healthy lifestyle by assessing hydration biomarkers and nutrients of a patient (Shajari et al., 2023).

Furthermore, wearable sensors are used not only by those patients who does not have access to doctors, but also during recovery period (Nasiri, S., & Khosravani, M. R. (2020). Patients can significantly pay less healthcare costs by minimizing the number of hospital and emergency room visits, which is very expensive for the patient and the healthcare system (Shajari et al., 2023). Recommendation and reminders are given in wearable technology to give patients insights about their personalized health and to aim one's health and lifestyle improvement, so that it can significantly reduce the risk of having diseases (Baig et al., 2017, as cited in Shajari et al., 2023).

According to Kuruvinashetti, et al., 2023, despite having a ton of advantages in having wearable sensors for personalized healthcare and disease detection, there has still many challenges faced such as risk of inaccurate readings and reliability of the data collected by this device. It could lead to panic and false alarms, or could also lead to missed opportunity for early detection of one's health issue. That is why it is needed to validate the technology with gold

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standard methods, such as blood chemistry and other relevant standard techniques. Also, there is also a rick of data breaches and unauthorized access to personal data. Healthcare providers and device manufacturers must be prioritize appropriate handling and extra care (Baig et al., 2017, as cited in Shajari et al., 2023).

Wearable technology is a very significant component in healthcare world especially in personalized health monitoring and for assessing early detection of diseases. These sensors, wireless communication, IoT, artificial intelligence, and biomedical engineering are the foundation of this kind of technology, as they are used in medical field. It still has current limitations and gaps present in existing studies, as they suggest ways to make digital healthcare solutions become more reliable and give accurate findings that focused on patient's health.

Statement of the Problem

Although major developments have occured in wearable sensor technologies, there are still challenges that continue to limit their full interconnection into the healthcare world. Although these devices provide advanced functions for continuous health monitoring and early disease detection, concerns remain about data accuracy, reliability, user comfort, and data privacy. Inconsistencies in examination methods and lack of standard clinical procedures make it difficult to fully assess and examine their full and real effectiveness in medical practice.

Objectives of the Study

This review targets to examine the improvement and current status of wearable sensor technologies that are used for personalized and early disease detection.
Specifically, this study aims to:

1. To analyze the evolution and evaluate the role of wearable sensor technologies used in healthcare monitoring systems.
2. To identify the current limitations, gaps, technical challenges, and reliability of the wearable sensor technologies.
3. To highlight future research directions and technological enhancements that are needed for broader adoption of wearable health monitoring systems.

As wearable sensor devices are speedily progressing and becoming more vital in digital healthcare practice, it is necessary to know their current capabilities and limitations. This review paper aims to discuss the development, applications, and technological progress of wearable sensor systems used for personalized health monitoring and early disease detection. Furthermore, the study identifies major challenges such as data reliability and accuracy, data privacy, and system integration that should be addressed to support wider use od these technologies in healthcare.

II. Methods and Procedures

A. Selection Criteria

The papers we included are centered on wearable or wearable-related sensor technologies that are obviously relevant to illness detection or health monitoring. In particular, we incorporated studies that:

- Discusses wearable or wearable-adjacent sensor systems designed for monitoring physiological or health-related signals;
- Focuses on applications in health tracking, early detection of disease, or personalized healthcare;
- Provides empirical data, technical review material, system design insights, or material/engineering advances pertinent to wearable systems; and
- Was accessible in full text and published in a peer-reviewed journal, reputable publisher venue, or as a comprehensive review.

Papers that did not give significant technical or application background, were inaccessible in full text, or had a major focus outside wearable sensor technology (e.g., entirely implanted systems with little emphasis on health monitoring) were not included in selection.

B. Screening Process

We first looked over titles and abstracts to weed out obviously irrelevant records after obtaining the initial search results. The remaining articles' full texts were then perused and assessed in light of the previously mentioned selection criteria. The reviewers iteratively discussed whether to include a paper, focusing on how the study directly advanced our understanding of wearable sensors in early disease detection or personalized health. The final collection consists of five studies whose substance and focus closely matched the review's goals.

C. Data Extraction

We gathered important information from various selected articles to compare and evaluate the findings across different situations and technologies. These are the data's we extracted from the different articles:

- Authors and year of publication
- Kind of wearable sensor technology
- Principal application:
  - Health monitoring vs Illness detection
- Key technological materials
- Stated performance
- Noted limits / Implementation issues

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We also added some aspects if available, such as:

- Sensor transduction methods
- System topologies
- Integration of analytics / Machine learning
- Discussion of usability / Deployment Considerations

We organized these data's in such a way to allow thematic comparison.

D. Thematic Organization

Because of the vastness of the nature of the topic we selected, we organized the Results section around themes that focuses on the rudimentary technological and operation insights arising from the literature. These themes emphasize the repeating concerns and topic across the ten publications, including: sensor technology and materials, device architecture and connectivity, application to health monitoring and disease detection, performance and real-world considerations, and challenges and future directions.

By making the review in this manner, it allowed us to view and understand how each articles table wearable sensing from an engineering and health point-of-view. It also emphasizes the ideas that are essential to present and future work in personalized health monitoring and early disease detection..

III. Results and Discussion

A. The difference and progression of wearable sensor technologies

Recent literature indicates a distinct evolution of wearable technology from basic activity trackers to full platforms capable of real-time sickness tracking. This revamps the fitness-focused wearables into biosensing devices that can be oriented clinically, and can also integrate versatile electronics, nanomaterials, and over-the-air communication for precise healthcare (Guk et al., 2019).

While Adeghe et al. allude to the categorization of devices sorted into physical monitoring systems, biochemical sensors, and platforms that are multi-mode (Adeghe et al., 2024), vital enabling modalities such as electrochemical, optical, and piezoelectric are also emphasized (Vo & Trinh, 2024). For gadget integration and comfort challenges, reducing and making the substrates flexible has allowed long usage without burdening the users (Abreu et al., 2026). Kurul et al. emphasize on these classification though system-level review. Part of the existing wearable taxonomy as specified by Kurul et al. are: microfluidics, multimodal sensing, and system-level aspects (Kurul et al., 2026). These inventions and innovations has refined consumer accessories into parts of customizable preventive health services.

B. Significance of cardiovascular health on health status tracking

One of the most advanced application field for wearable sensors is cardiovascular monitoring. The primary wearable technology for cardiovascular monitoring are combined from the data's of these different studies: ECG patches, PPG-based heart-rate monitors, and cuffless blood-pressure estimation techniques (Xie et al., 2025, Guk et al., 2019).

ECG wearables is one promising aspect in detecting arrhythmias as studies show, but it lacks in preventing motion artifacts and signal noise (Xie et al., 2025). Meanwhile, improving the hardware such as, nanostructured electrodes and better skin interfaces helps on reducing the signal noise. Additional software features such as filtering and artifact rejection are vital in the creation of the usability of these devices in a clinical setting (Guk et al., 2019; Kurul et al., 2026).

Reviewers consistently highlight the importance of large-scale clinical studies and systematized validation procedures before wearable technologies can be utilized more in practice, despite the many advancements made (Xie et al., 2025; Kurul et al., 2026).

C. The improvement in biochemical and biosensing wearables

These are largely commemorated as the next level for disease monitoring and tailored medicine: electrical signals, biochemical sensing (sweat, interstitial fluid, saliva, tear). Prominent in the literature are electrochemical wearable biosensors for glucose, lactate, and other metabolites. These offer non-invasive continuous monitoring (Vo & Trinh, 2024; Abreu et al., 2026). To boost the keenness and accuracy, reviews emphasize materials and surface engineering, nanostructured electrodes, conductive polymers, and antifouling coatings (Guk et al., 2019; Abreu et al., 2026).

At the same time, some challenges keep appearing across different sources: signal noise & instability under motion, biofouling, different variation in analyte concentration, and calibration drift (Vo & Trinh, 2024; Xie et al., 2025). Incorporating biochemical sensing with robust sampling, on-sensor preprocessing, and secure data linkages on a system-level evaluation remains a noble engineering problem before routine clinical implementation (Kurul et al., 2026).

D. AI, analytics, and predictive models for wearable data

The key to ensure the individualization of predictive care is the unification of AI machine learning and wearable sensors. Huang et al. examines different approaches of AI to cardiovascular data, emphasizing common model families such as:

- Classical machine-learning classifiers
- Deep learning
- Hybrid pipelines

as well as data-preprocessing requirements:

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- Artifact removal
- Segmentation

and lastly, deployment challenges:

- Class imbalance
- Personalization
- Interpretability

(Huang et al., 2022).

AI greatly boosts the significance of wearable technology in clinical trials by granting pattern recognition and discovery (e.g., arrhythmia subtypes, early deterioration symptoms) that raw signals cannot reveal by itself (Huang et al., 2022; Xie et al., 2025).

Researchers indicate that the development of an algorithm must be with sample datasets, comprehensive cross-checking, bias identification, and subsequent clinical trial, to move forward beyond the proof-of-concept research. (Huang et al., 2022; Kurul et al., 2026).

E. Implementing, documenting, and compensating for the real-world

The distinctiveness between laboratory results and real-world credibility are a common factor across the different studied literatures. Despite the display of impressiveness from the wearable systems' accuracy under controlled preliminary occurrences, there's a noticeable decline in the performance in actual usage. This is due to motion artifacts, ambient impacts, and the different factors across users (Xie et al., 2025; Kurul et al., 2026).

The significance of systematic validation rules, multi-site clinical trials of diverse populations, unbiased reports on sensitivity and specificity, and assessments on usability that inspect wear time, user comfort, and adherence, are what researchers highlight to address the gap (Xie et al., 2025; Abreu et al., 2026).

Beyond functional capability, analysis on a system-level stresses on the practical constraints that affects management, such as: battery life, energy efficiency, security and data transmission privacy, authorization protocols, and it's incorporation into operating clinical workflows (Kurul et al., 2026; Huang et al., 2022).

F. Synthesis: analytical priorities and the current state of the field

Despite the fast evolution of the technology, it still faces major problems in translating these improvements and innovations into clinical practice, when the reviewed and compiled studies are taken together. Wearable devices are significantly becoming cosmopolitan by having breakthroughs continue to develop their capabilities, in areas such as:

- Materials science
- Flexible electronics
- Microfluidics
- and multimodal system design

(Guk et al., 2019; Kurul et al., 2026).

Meanwhile, advancements in analytics especially AI and signal interpretation are further improving wearable devices in providing more useful data in the clinical field, specifically for monitoring of cardiovascular health (Huang et al., 2022; Xie et al., 2025).

Except, transferring of these devices from prototypes to the use of customers everyday for clinical usage is not an easy path. Some factors need more consideration, such as: doing more thorough clinical trials and creating systematized criteria, preventing signal drift and fouling by closely connecting biochemical sampling with sensor design, keeping comfortability while improving battery life and signal connectivity, and the careful testing and checking of different AI models to guarantee that they are reliable, understandable, and fair.

These points are further advocated by showing the expansion of digital ecosystem, through microfluidics and multimodal integration, and highlighting the pragmatic difficulties in applying AI machine learning to wearable health data in a real-world scenario (Kurul et al., 2026; Huang et al., 2022).

IV. CONCLUSION

This review paper is conducted to assess current limitations, gaps, and technological challenged in wearable sensor systems for personalized health monitoring and early detection.

Based on the reviewed existing studies, wearable sensor technologies have evolved quickly from just a tracking tool for fitness into refined technology in charge of monitoring one's health and early detecting of possible diseases. This rapid advancement of multipurpose electronics have contributed to the development of these devices. Meanwhile, biochemical sensing technologies are emerging as a promising frontier for personalized medicine, although challenges such a unstable signal, drift calibration, and biofouling persist.

Artificial intelligence integration and machine learning better enhances clinical relevance of wearable sensors by enabling predictive analytics and more actual and accurate detection of diseases. However, even though these devices perform very well in the laboratory, their use in healthcare is still limited. Challenges such as differences between users, data accuracy, privacy concerns, battery life, regulatory rules, and the lack of standardized validation protocols are holding them back.

Overall, the field is at a crucial state. Technology is moving forward incredibly fast, but for wearable sensors to be widely used in healthcare, we still need large-scale studies to prove that they really work, systems that are more reliable, secure ways to handle patient data, and models that doctors can easily understand. It is really important to discuss these challenges so that wearable devices can reach their full potential in personalized healthcare monitoring and early disease detection.

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