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Wearable Devices for Arrhythmia Detection: Clinical Utility, Limitations, Ethical Considerations and Future Directions

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ABSTRACT

The new era of wearable devices has brought us the potential, though limited, to monitor our health. The main purpose of cardiovascular monitoring is the detection of AF (atrial fibrillation). Modern wearables can not only detect but also send real-time alerts to users, often before they can feel the arrhythmia. The quick adoption of these tools into daily life, though, has also opened up many discussions—technical, medical, and ethical (sometimes all tangled together). Many wearables remain outside the official validation of regulatory bodies, and their accuracy shifts depending on the group being tested (older patients or those with multiple conditions tend to experience more variability). Collecting highly sensitive cardiac data also introduces another layer of concern, especially when companies control the information (users often accept lengthy agreements without reading them at all). Smartwatch notifications regularly push people to book a consultation, even if the trigger was something minor or harmless. Healthcare providers may find opportunities in this trend—for example, by spotting disease earlier—but at the same time the system risks becoming overloaded by the extra number of visits. These devices are not yet capable of replacing traditional diagnostics, such as the 12-lead ECG, but they are reshaping the way patients engage with their health. Wearables merge consumer gadgets with clinical tools, making careful evaluation, regulation, and evidence-based integration essential to help patients benefit safely (minimizing potential harm).

Keywords: Monitoring heart health with wearables, Early detection of atrial fibrillation (AF), Safeguarding data privacy and ethics, Incorporating digital health into clinical practice

1. INTRODUCTION

Wearable technologies have advanced remarkably in the past few years—from counting steps to continuously monitoring heart rhythm, often without the user knowing. Smartwatches and ECG patches now use photoplethysmography (PPG) and single-lead ECG sensors (while the standard in medical diagnostics is the 12-lead ECG) to detect conditions such as atrial fibrillation (AF)—an often silent arrhythmia that significantly increases the risk of stroke and mortality. Early detection is crucial, and wearables can shorten the time from the first manifestation of symptoms to diagnosis.

Recent studies reinforce this potential. Smartwatches, rings, ECG patches, and smart textiles increasingly detect atrial fibrillation. These modern devices can often outperform traditional Holter monitors, especially for diagnosing AF during longer monitoring periods (Abdelrazik et al., 2025). A systematic review and meta-analysis published in May 2025 found that automated smartwatch ECGs achieved about 86 % sensitivity and 94 % specificity. Manual interpretation by qualified clinicians raised sensitivity to 96 % and specificity to 95 % (Iqhrammullah et al., 2025). A validation study published in JMIR Formative Research directly compared leading consumer devices—including Apple Watch, KardiaMobile, FibriCheck, and Preventicus—against the 12-lead ECG. The devices demonstrated very high accuracy, but older adults and individuals with frequent extrasystoles had a larger share of readings that could not be interpreted (Wouters et al., 2025).

Performance is improving: the Basel Wearable Study showed that over two years (2021–2023), inconclusive rates for AF detection (based on single-lead ECG) decreased—from 14–22 % down to 6–10 %—likely reflecting algorithm updates on devices like Apple Watch, Fitbit Sense, Samsung Galaxy Watch, and Withings ScanWatch (Isenegger et al., 2024). Yet even as accuracy rises, concerns persist: alerts can lead to false positives, unnecessary anxiety, and heavy strain on clinical workflows.

Non-clinical platforms in healthcare are raising important ethical and legal questions (for example, about patient rights and responsibilities). These questions focus on data ownership, equity, and informed consent, as well as on the evolving dynamics of healthcare relationships—especially when these platforms collect and handle sensitive physiological data outside traditional clinical settings (such as wearable device readings or app-collected metrics) (Capulli et al., 2025). In everyday life, wearables can create new uncertainties. Users may report heart problems based only on device alerts, often without full medical context (for instance, an irregular heartbeat reading). At the same time, healthcare providers must interpret this consumer-generated data, which adds pressure and complexity to their decision-making.

This review examines the latest evidence on the clinical value and diagnostic accuracy of wearable devices. Further, we discuss the practical challenges of unsupervised use and explore the ethical and regulatory issues raised by tech-driven cardiac monitoring. As wearables become more integrated into the healthcare system and self-care, it is essential to understand their potential benefits as well as their limitations.

2. REVIEW METHODS

This review explored recent studies on wearable devices and their role in detecting arrhythmias, particularly atrial fibrillation — databases used for this research included PubMed, Scopus, Cochrane Library, and Google Scholar. We also identified some articles by checking the reference lists of key papers and by including newer, still-under-review studies from preprint platforms. The review focused on recent, well-grounded studies (especially from January 2024 and May 2025) that investigated how smartwatches, ECG patches, and other health-tracking wearables operate in real-life settings. To qualify for inclusion, studies had to provide data, make comparisons, report real-world experiences, or offer insight into how these devices are changing healthcare. The papers included in this research had to address device accuracy, patient responses, and the impact on earlier diagnosis or medical contact. By contrast, the review excluded studies that focused on implanted devices (such as loop recorders) or those unrelated to heart rhythm monitoring. The review excluded reports without access to full text, individual case reports, and general opinions without data. It included only English-language publications. The review paid special attention to articles that addressed issues beyond strictly medical questions—such as data privacy, unequal access, or whether technology companies should handle sensitive health information. We followed PRISMA guidelines to select studies, and the process is illustrated in Figure 1. We used PRISMA guidelines to select the studies (Figure 1).

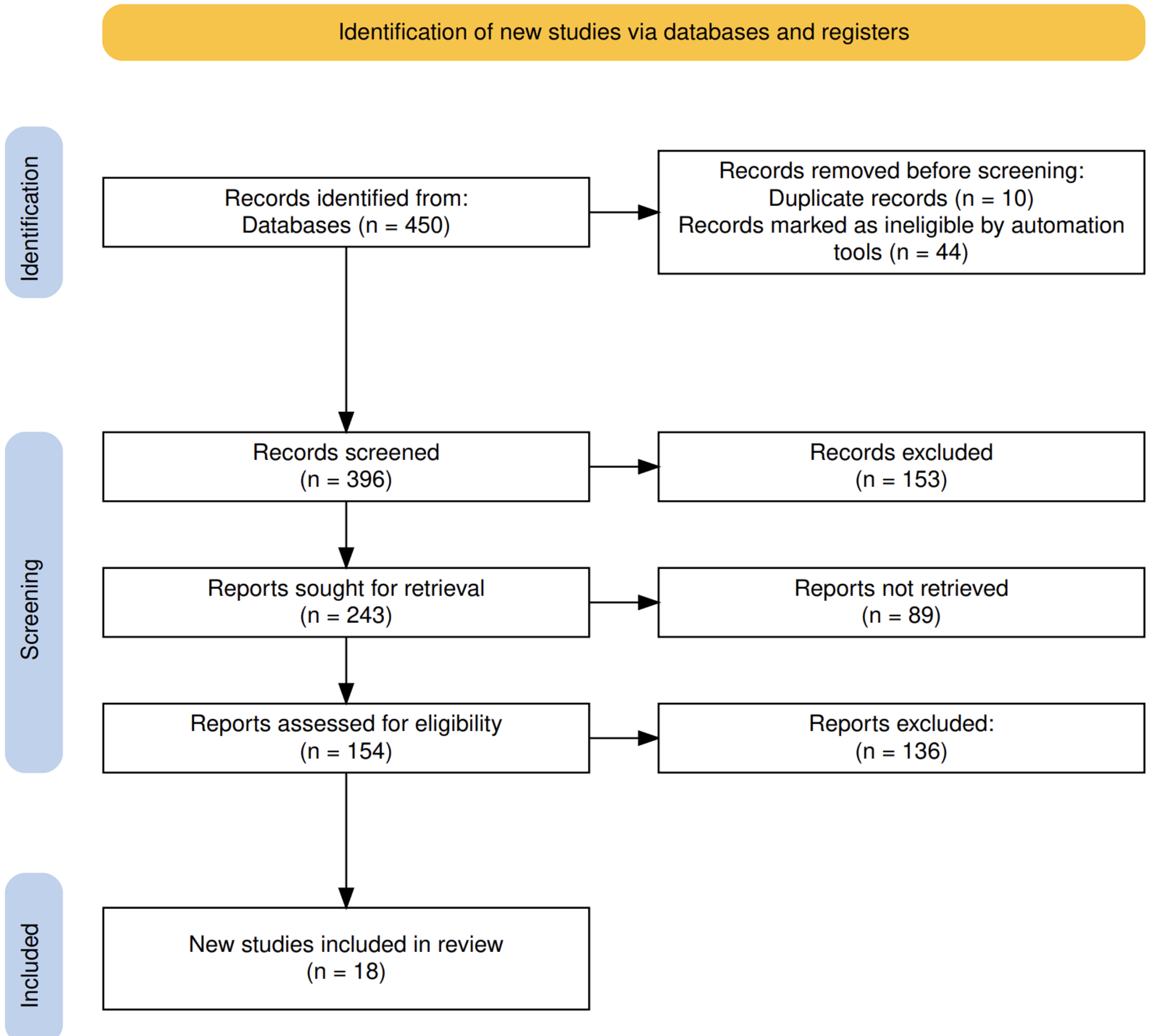

Figure 1. PRISMA flow diagram

3. RESULTS AND DISCUSSION

Diagnostic performance of wearable devices

Wearable heart-monitoring devices—including smartwatches and ECG patches—have achieved remarkable accuracy for non-clinical tools. A 2024 meta-analysis reported that photoplethysmography-based smartwatches detected atrial fibrillation with approximately 97.4 % sensitivity and 96.6 % specificity, while ECG chest patches achieved around 96.1 % sensitivity and 97.5 % specificity (Sibomana et al., 2025). A 2025 focused re-analysis of Apple Watch data found a pooled sensitivity of about 94.8 % and specificity of 95 %, which are substantial under ideal conditions (Shahid et al., 2025). However, the way results are generated or interpreted makes a real difference. In one internal validation study, automatic smartwatch ECG readings reached about 88 % sensitivity and 86 % specificity, but when a clinician reviewed the tracings, sensitivity increased to over 94 % (Abu-Alrub et al., 2022). All leading technology companies continue to update firmware and algorithms in their smart products. The Basel Wearable study shows that inconclusive readings fell from 14–22 % in 2021 to 6–10 % by 2023 across devices such as Apple Watch, Fitbit Sense, Samsung Galaxy Watch, and Withings ScanWatch (Isenegger et al., 2024). Despite these advances, real life use remains imperfect. Readings can be affected by movement, skin tone, trembling, inadequate sensor contact, or low battery. False positives persist, sometimes causing undue anxiety or leading to needless clinic visits. On the flip side, many people have received their first-ever AF diagnosis following a device alert. These tools hold value as screening aids—but they are not substitutes for 12 lead ECGs or specialist evaluation. Instead, they occupy a new space between consumer gadget and clinical assistant, particularly when alerts are reviewed or interpreted in a healthcare setting. To compare the accuracy of different wearable device models in detecting atrial fibrillation (Table 1).

Table 1. Diagnostic Accuracy of Selected Wearable Devices for Atrial Fibrillation Detection

Device Type	Technology	Sensitivity around (%)	Specificity around (%)	Important Notes
Smartwatches	Photoplethysmography (PPG)	97.4	96.6	Good accuracy for AF detection
Chest ECG Patches	Single Lead ECG	96.1	97.5	Performs well in clinical use
Apple Watch (2025 re-analysis)	ECG	94.8	95	Based on pooled analyses under optimal conditions
Smartwatch ECG (automatic)	ECG	88	86	Results from internal validation with automated interpretation
Smartwatch ECG (clinician review)	ECG	94	–	Sensitivity improves with manual interpretation

Limitations and challenges

Wearable devices for atrial fibrillation detection bring promising opportunities, but the path to clinical reliability can be challenging. Factors such as movement, sweating, a loose strap, or not wearing the device can reduce signal quality and affect detection accuracy. Even when participants wore the devices consistently, the results reported by researchers remained unclear. Questions may arise regarding whether the system operates independently.

Then comes the burden on the healthcare system. Notifications from consumer wearables - often vague, non-specific, or false alarms - are increasingly prompting patients to seek care. While early detection is good, overdiagnosis and patient anxiety are growing concerns. A 2025 paper reported that clinicians frequently receive unverified data from devices that are not integrated with electronic health records (Straiton et al., 2024).

Integration into the healthcare system is another hurdle. Although some wearables can export data to PDFs or companion apps, clinicians rarely integrate this information into medical records in a streamlined way. An extensive observational study emphasized that clinicians will find these devices helpful only if they can easily interpret the data within the clinical workflow (Ghadi et al., 2025).

Looking Ahead – Predicting Atrial Fibrillation

Predictive analytics is beginning to transform how clinicians detect atrial fibrillation (AF). New AI models now aim to anticipate AF before arrhythmias occur, rather than reacting after the fact. By training algorithms on extensive ECG datasets, we can later achieve predictive performance that surpasses traditional clinical scores, such as CHARGE-AF (Karakasis et al., 2025). These algorithms may improve monitoring in high-risk individuals, but they are not without challenges. False alerts remain possible, and how users will react to early warnings—whether with anxiety, reassurance, or unnecessary action—is still unknown. Clinicians are likely to adopt predictive models more widely only when these tools provide greater individualization and improved interpretability (Bench et al., 2025).

Ethical, Regulatory, and Data Privacy Issues

Wearable devices for atrial fibrillation monitoring bring several challenges. Privacy, ethical, and regulatory issues are important. Companies often collect sensitive data outside clinical settings (for example, heart rate or sleep patterns), which can raise questions about consent and data ownership. Limited access could worsen healthcare inequalities, and unclear follow-up after alerts can increase patient anxiety and strain providers (Rosman et al., 2024).

Future Directions

We can witness rapid progress in smart technology (specifically with AF monitoring functions). Some studies describe the latest achievements in this field and also make assumptions about future developments. One study described a deep-learning model, WARN, that predicts atrial fibrillation episodes about 30 minutes in advance using only R-R interval data. The model achieved approximately 83% accuracy and shows potential for real-time use on smartwatches (Gavidia et al., 2024). AI-ECG systems trained on very large (and still growing) ECG datasets are starting to show real clinical value. These models are able to catch subtle electrical changes that point to paroxysmal AF, even when patients appear to be in normal sinus rhythm. Reported AUC values range from 0.87 to 0.90, which is impressive. In fact, they often perform better than traditional clinical scores-CHARGE-AF is one example-and this performance supports more proactive and earlier screening strategies (Christopoulos et al., 2020). Another promising idea, sometimes called multimodal sensing, takes a different route. Instead of focusing on just one signal, researchers combine ECG and PPG with basic physiological measurements (skin temperature, breathing rate, or both) (Papalamprakopoulou et al., 2024).

4. CONCLUSION

Wearable devices are undoubtedly influencing the way we detect and monitor AF. Readings from these devices are becoming increasingly accurate, even without clinician supervision. Replacing standard diagnostics like the 12-lead ECG remains unachievable, but the role of wearables is becoming more established. However, this technology brings several challenges, including data integration, false positives, and privacy concerns. We have to address these issues sooner or later. Future directions in the development of smart wearables are promising. From the latest studies, we can learn about predictive models that can warn potential users of AF before it starts, multimodal sensing that connects heart rhythm data with monitoring other basic life functions, and AI-enhanced ECG interpretation. These improvements could further maximize their potential and transform them into proactive tools for healthcare workers.

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Informed consent

Not applicable.

Ethical approval

Not applicable.

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Conflict of interest

The authors declare that there is no conflict of interest.

Data and materials availability

All data associated with this work are present in the paper.

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