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ATRIAL FIBRILLATION, WEARABLE TECHNOLOGIES AND ARTIFICIAL INTELLIGENCE: CURRENT EVIDENCE, CLINICAL UTILITY AND LIMITATIONS

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ABSTRACT

Background: Atrial fibrillation is the most common sustained cardiac arrhythmia in adults and represents an important clinical and public health problem because of its association with stroke, mortality, disability, and healthcare burden. Its paroxysmal and frequently asymptomatic course limits the effectiveness of conventional diagnostic strategies based on occasional electrocardiographic recordings.

Aim: This narrative review aims to summarise current evidence regarding the use of wearable technologies and artificial intelligence for the detection of atrial fibrillation, with particular emphasis on diagnostic accuracy, clinical utility, and principal limitations.

Methods: A structured literature search was performed using PubMed, Scopus, Web of Science, and Google Scholar. Studies published between 2021 and 2026 were primarily considered. Search terms included “atrial fibrillation,” “wearable technologies,” “smartwatch,” “electrocardiography,” “photoplethysmography,” “artificial intelligence,” “machine learning,” and “diagnostics.” Priority was given to original studies, systematic reviews, meta-analyses, and clinically relevant review articles concerning wearable devices, artificial intelligence, and atrial fibrillation detection. Earlier landmark studies were included when they were necessary to explain key evidence discussed in recent reviews and meta-analyses.

Results: Wearable devices such as smartwatches, fitness bands, and portable ECG systems allow longer heart rhythm monitoring in daily life and may help detect paroxysmal and clinically silent atrial fibrillation. ECG-based devices are more consistent with current diagnostic standards, whereas photoplethysmography-based systems are more accessible and can provide passive rhythm monitoring. Artificial intelligence, especially machine learning and deep learning, can support signal interpretation, arrhythmia recognition, and risk prediction. However, diagnostic performance reported in controlled studies may not always translate directly into real-world clinical practice.

Conclusions: Wearable technologies and artificial intelligence offer a promising way to support atrial fibrillation screening and monitoring. They may improve early detection, especially in asymptomatic individuals, but should not replace standard diagnostic methods. Photoplethysmography-based alerts should be regarded as screening signals, while a final diagnosis of atrial fibrillation should still be confirmed by ECG in an appropriate clinical context. More large-scale studies are needed before these tools can be widely implemented in routine practice.

KEYWORDS

Atrial Fibrillation, Wearable Devices, Smartwatch, Artificial Intelligence, Photoplethysmography, Electrocardiography, Screening

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Introduction

Atrial Fibrillation as a Clinical and Public Health Problem

Atrial fibrillation (AF) is the most common arrhythmia encountered in clinical practice, and its prevalence increases markedly with age, which is one of the main predisposing factors. Other important risk factors include arterial hypertension, obesity, and diabetes mellitus. The development of AF is associated with several mechanisms, including structural and electrical remodelling of atrial tissue [1].

Stroke is a leading cause of death, disability, and long-term impairment worldwide. AF is linked to a significantly increased risk of stroke and a growing public health burden. Strokes related to AF often have a more severe clinical course, higher mortality, and greater risk of recurrence than strokes not associated with AF [2].

The diagnosis of AF is challenging because the condition is often asymptomatic and paroxysmal. Implantable and wearable electronic devices for cardiac monitoring have made it possible to better appreciate the scale of subclinical atrial fibrillation (SCAF). In these patients, short and asymptomatic episodes of atrial arrhythmia are frequently detected. Silent AF generally refers to AF without symptoms, whereas SCAF or atrial high-rate episodes are usually detected by implantable or wearable devices and may lack conventional

surface ECG documentation. Despite the absence of symptoms, SCAF is not a benign phenomenon and is associated with an increased risk of cardiovascular events and mortality. Even more concerning is the fact that the first clinical manifestation may be a severe or fatal ischemic stroke [3,4].

In summary, because AF is common, often asymptomatic, and may lead to serious health problems, there is a clear need for better strategies for early detection.

Disadvantages of Traditional Diagnostic Methods

Although the electrocardiogram (ECG) is more than 100 years old and continues to play a very important role in clinical medicine, it remains a rapid and inexpensive bedside test. It is commonly used in routine diagnostics, including in the form of the standard 12-lead ECG [1,4].

However, standard diagnostic methods have limited usefulness when atrial fibrillation is paroxysmal, asymptomatic, and difficult to capture. Holter monitors and 14–30-day mobile cardiac telemetry may miss intermittent arrhythmias if they are not present during the recording period. Therefore, silent or paroxysmal AF may remain undetected when an ECG showing sinus rhythm is recorded before or after an AF episode [4].

The actual number of AF episodes is probably substantially underestimated. Diagnosing AF only after a clinical event means that the opportunity to implement primary prevention may already have been lost. Long-term ECG monitoring is more effective than short-term ECG monitoring in detecting previously unrecognised AF [3].

Although long-term monitoring methods, such as extended Holter recordings or implantable loop recorders, increase detection rates, their use is usually limited to selected patient groups because of cost, availability, and practical issues. Therefore, population-level screening strategies based solely on traditional methods remain insufficient [5].

This emphasises the need to develop alternative monitoring technologies that could improve detection rates and support earlier clinical evaluation.

Study Objectives

Wearable technologies and artificial intelligence have developed rapidly in recent years, particularly in the field of cardiovascular care. This has created a growing need to summarise and critically evaluate the available evidence. The aim of this study is to review the current literature on the use of wearable devices and artificial intelligence in the detection and diagnosis of atrial fibrillation. Particular emphasis is placed on diagnostic accuracy, clinical application, and the main limitations identified to date.

Methodology

This review used a structured narrative approach. PubMed, Scopus, Web of Science, and Google Scholar were searched for studies published primarily between 2021 and 2026. The search strategy included combinations of the following terms: “atrial fibrillation,” “wearable technologies,” “smartwatch,” “electrocardiography,” “photoplethysmography,” “artificial intelligence,” “machine learning,” and “diagnostics.”

Priority was given to original studies, systematic reviews, meta-analyses, and clinically relevant review articles concerning wearable devices, artificial intelligence, and atrial fibrillation detection. Earlier landmark studies were included when they were necessary to interpret important findings discussed in recent literature, particularly large population studies and major validation trials. Articles were selected based on clinical relevance, methodological quality, and their contribution to understanding diagnostic accuracy, screening utility, and implementation limitations.

Wearable Devices for Detecting Atrial Fibrillation

Based on their operating principles and diagnostic applications, wearable devices for detecting atrial fibrillation can be divided into several types. The most important categories include portable or wearable electrocardiographic (ECG) devices that allow single-lead or multi-lead recording, as well as smartwatches and fitness bands equipped with photoplethysmographic (PPG) sensors [6,7].

ECG-based devices directly detect the electrical activity of the heart using electrodes placed in contact with the patient’s skin. In single-lead systems, the recording most commonly corresponds to lead I. Because ECG directly monitors cardiac electrical activity, ECG-based wearable technologies are more consistent with current diagnostic criteria, and electrocardiographic documentation remains the standard for diagnosing AF [4,8].

ECG-based wearable and handheld devices differ in recording duration, mode of use, and clinical setting. According to the ESC guidelines, ECG documentation remains necessary for the clinical diagnosis of AF, including recordings obtained from wearable ECG devices when they are of sufficient quality and duration [4]. In the review by Wang et al., ECG-based wearable and portable systems described for arrhythmia detection included devices such as KardiaMobile, Zio Patch, ECG Check, and other patch-based or smartphone-connected ECG systems. Some devices provide short single-lead recordings requiring active user participation, whereas patch-based systems can allow longer ambulatory monitoring [7].

Extended ECG monitoring may increase the detection of previously unrecognised or paroxysmal AF compared with short-term or occasional recordings. Wang et al. discussed patch-based ECG monitoring, including the Zio Patch, as an example of prolonged wearable ECG monitoring that may improve AF detection by extending the recording period beyond a standard short ECG examination [7]. However, diagnostic performance differs between studies because of differences in population characteristics, AF prevalence, reference standards, recording duration, and study design [4,7].

Recent reviews focused on AI-powered ECG interpretation also support the central role of electrocardiographic data in AF detection. Nasser et al. described how artificial intelligence, particularly machine learning and deep learning, can analyse ECG recordings, support automated rhythm classification, and potentially improve AF detection and prediction beyond conventional ECG interpretation alone [11].

In contrast, PPG-based systems work by detecting abnormalities in pulse wave signals rather than by recording the electrical activity of the heart. Photoplethysmography is an optical method that detects changes in microvascular blood volume by emitting light into the skin and sensing the light that is reflected back. The device analyses deviations in peak-to-peak intervals and pulse morphology. If irregularities or variations are observed, the system may notify the user. PPG allows passive and non-invasive rhythm monitoring over extended durations in wearable devices such as smartwatches, wristbands, armbands, finger-bands, and other sensor-based devices. The data collected by PPG are usually processed by a linked mobile application or cloud-based platform, where algorithms analyse pulse irregularity, signal quality, and rhythm variability. However, because PPG does not directly record cardiac electrical activity, abnormal PPG findings should be considered screening alerts and require ECG confirmation before a clinical diagnosis of AF is made [7,9].

PPG-based devices have been evaluated both as handheld and wearable systems. Handheld PPG devices commonly use the smartphone camera as the light source and the fingertip to obtain the PPG signal. Devices and applications described in the literature include FibriCheck, CardioRhythm, Preventicus, and PULSE-SMART. Their recording times differ between systems, and their diagnostic performance depends on signal quality, recording conditions, reference standard, and the population studied. Although several studies have reported high diagnostic accuracy for PPG-based AF detection, these results should be interpreted with caution because PPG does not directly record cardiac electrical activity [9].

Wearable PPG devices represent a heterogeneous group. The specific devices mentioned in the cited literature include smartwatches, wristbands, armbands, finger-band sensors, and earlobe sensor devices. Large population-based studies, including the Apple Heart Study by Perez et al. and the Fitbit Heart Study by Lubitz et al., have shown that PPG-based irregular rhythm notifications may help identify individuals who require further ECG-based assessment. In the Apple Heart Study, the positive predictive value of an irregular pulse notification for AF was 84%, whereas the Fitbit Heart Study reported a positive predictive value of 98.2% among participants with an irregular rhythm notification and analyzable ECG patch monitoring [18,19]. These findings support the usefulness of PPG-based wearables for broad screening and early alerts. However, PPG-derived detection is generally more vulnerable to artefacts than ECG-based detection [9].

A systematic review and meta-analysis by Prasitlumkum et al. evaluated the diagnostic accuracy of smart gadgets and wearable devices for atrial fibrillation detection. In this analysis, smartphones showed a sensitivity of 94% and specificity of 96%, while smartwatches showed a sensitivity of 93% and specificity of 94%. These findings suggest that smart devices may be useful in detecting possible AF, although the results should be interpreted with caution because of substantial heterogeneity between included studies [13].

A more recent systematic review and diagnostic meta-analysis by Barrera et al. confirmed the strong performance of smartwatches in identifying atrial fibrillation. This analysis included 26 studies and 17,349 patients and reported an overall sensitivity of approximately 95%, specificity of approximately 97%, and a pooled AUC of 0.97. Device performance varied, with the Apple Watch and Samsung smartwatches achieving sensitivity and specificity above 90% [14]. Photoplethysmography-based models showed diagnostic accuracy comparable to electrocardiogram-based models in this meta-analysis, although broader evidence indicates that PPG-based AF detection may be slightly less accurate than ECG-based systems. This indicates that both PPG

and ECG technologies may play an important role in AF detection; however, their clinical application depends on recording conditions, signal quality, and appropriate interpretation of results [9,14].

ECG recordings from smartwatches may be useful as a confirmatory tool when AF is suspected, especially if they are interpreted by a physician. In contrast, PPG-based alerts may support screening and monitoring outside clinical settings [8,9].

Overall, wearable devices and AI-based systems have considerable potential in the detection of atrial fibrillation. They may increase detection rates, particularly among asymptomatic individuals, and lead to earlier clinical assessment. However, they should be regarded as a complement to standard diagnostics rather than a replacement. PPG-based technologies are most appropriate for screening and alert generation, whereas ECG-based recordings remain necessary for confirmation of AF in the appropriate clinical context.

Diagnostic Comparison and Synthesis of Evidence

ECG- and PPG-based technologies have different roles in AF detection. ECG-based devices record cardiac electrical activity and can provide diagnostic evidence of AF, while PPG-based devices detect irregular pulse wave patterns and are mainly useful for screening and early alerts. Therefore, suspected AF detected by PPG should be confirmed by ECG [7,9].

Diagnostic accuracy depends on signal quality, recording conditions, device type, algorithm performance, and user behaviour. Results obtained in controlled studies may therefore differ from real-world performance, where motion artefacts, inconsistent device use, and poor-quality recordings are more common [10,14].

Artificial intelligence can improve AF detection by analysing ECG or PPG signals and identifying patterns associated with arrhythmia. AI models are trained on labelled datasets, usually divided into training, validation, and testing groups. During training, the algorithm learns features such as irregular RR intervals, absence of organised atrial activity on ECG, or irregular pulse wave patterns in PPG signals [7,15].

AI can be implemented directly in wearable devices for simple real-time analysis or through a smartphone application or cloud platform for more complex processing. Its use in clinical practice depends on technical factors such as battery life, processing capacity, signal quality, and data protection. Even when AI is built into wearable devices, suspected AF should still be verified by ECG and interpreted in an appropriate clinical context [8,12].

Discussion

Wearable technologies extend heart rhythm monitoring beyond occasional recordings performed in clinical settings and may help identify paroxysmal or asymptomatic atrial fibrillation that would otherwise remain undetected. Large population-based studies, such as the Apple Heart Study and the Fitbit Heart Study, indicate that PPG-based irregular rhythm notifications may be useful in selecting individuals who require further ECG-based assessment. At the same time, diagnostic performance observed in studies should not be treated as identical to effectiveness in everyday clinical practice, because real-world accuracy may be influenced by differences between devices, algorithms, recording conditions, signal quality, and study populations. Meta-analyses by Prasitlumkum et al. and Barrera et al. confirm high sensitivity and specificity of smart devices and smartwatches, but also highlight the substantial heterogeneity of the available evidence. Therefore, implementation of these technologies should rely on clear diagnostic pathways, in which alerts from wearable devices serve as screening signals rather than final diagnoses. Before therapeutic decisions are made, ECG confirmation and interpretation in the appropriate clinical context remain necessary. Future research should focus not only on diagnostic accuracy, but also on clinical outcomes, cost-effectiveness, patient adherence, and integration with existing healthcare systems. Further work is also needed to improve the robustness of algorithms against motion artefacts and variable signal quality, and to determine whether combining ECG, PPG, clinical information, and other physiological parameters can improve risk stratification without increasing the number of false-positive alerts.

Conclusions

Wearable ECG and PPG technologies, supported by artificial intelligence, may improve the early detection of atrial fibrillation, particularly in individuals with intermittent or asymptomatic arrhythmia. ECG-based devices remain most relevant for diagnostic confirmation, whereas PPG-based systems are better suited for screening and early alerts. These tools should complement, rather than replace, standard ECG-based diagnosis. Further real-world studies are needed to determine their clinical effectiveness, cost-effectiveness, and optimal integration into healthcare systems.

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