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WEARABLE-DETECTED ATRIAL FIBRILLATION ALERTS: CLINICAL YIELD, PSYCHOLOGICAL BURDEN, EQUITY, AND HEALTH-SYSTEM CONSEQUENC-ES - A STRUCTURED REVIEW

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ABSTRACT

Background: Consumer smartwatches and wearable electrocardiographic monitors have moved part of atrial fibrillation (AF) screening into continuous, patient-initiated surveillance.
Objective: To evaluate wearable-enabled AF detection in relation to diagnostic yield, clinical outcomes, overdiagnosis, psychological effects, health care utilization, equity, and governance.
Materials and Methods: PubMed/MEDLINE was searched, with supplementary citation and guideline tracking. Twenty-nine publications were included in a structured narrative synthesis.
Results: Large consumer-device studies found that irregular-rhythm notifications were un-common, and subsequent AF confirmation varied with device type, timing, and baseline risk. Randomized screening trials generally increased AF detection and anticoagulant initiation, but most did not demonstrate reductions in stroke, mortality, or hospitalization. Supported monitor-ing programs usually did not increase anxiety, whereas observational studies of routine weara-ble use identified greater symptom preoccupation, treatment concern, clinician contact, and di-agnostic activity. Consumer ownership and digital capability may also reproduce existing ine-qualities in access.
Conclusions: A photoplethysmographic alert should initiate risk assessment and electrocardiographic confirmation rather than be treated as a diagnosis or an indication for therapy. Clinical value is more likely when screening is targeted, follow-up responsibility is ex-plicit, communication reduces uncertainty, and programs evaluate patient-important outcomes, workload, and equity alongside detection yield.

KEYWORDS

Atrial Fibrillation; Wearable Devices; Screening; Overdiagnosis; Health Anxiety; Health Care Utiliza-Tion

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1. Introduction

Atrial fibrillation (AF) is the most common sustained cardiac arrhythmia and an important risk factor for ischemic stroke, heart failure, cognitive decline, hospitalization, and premature death. Because AF may be both paroxysmal and asymptomatic, a brief electrocardiographic recording during a routine visit can miss clinically relevant episodes. Wearable technologies offer a way to narrow this diagnostic gap by monitoring pulse rhythm repeatedly or continuously in daily life. Current devices use photoplethysmography (PPG), a single-lead electrocardiogram (ECG), or both. PPG-based systems detect pulse irregularity during passive surveillance, while a single-lead ECG provides an electrical tracing that a clinician can review. These capabilities are now available on consumer devices, not only on prescribed medical equipment.

The clinical rationale for wearable screening is appealing: earlier identification of undiagnosed AF could lead to anticoagulation in patients at elevated thromboembolic risk and prevent stroke. For screening to achieve that aim, however, several conditions must be met. The device must detect a valid irregular signal, an interpretable ECG must confirm AF, the episode must carry enough prognostic weight to justify treatment, and treatment must offer more benefit than harm. Accuracy in a selected validation cohort is therefore not equivalent to population-level screening benefit. In 2022, the US Preventive Services Task Force found insufficient evidence to determine the balance of benefits and harms of screening asymptomatic adults for AF (US Preventive Services Task Force, 2022). North American guidance likewise places wearable data within clinician-directed rhythm assessment and individualized management, rather than treating consumer-device output alone as a basis for diagnosis or anticoagulation (Joglar et al., 2024).

Wearables also relocate part of the diagnostic process. Consumers often initiate monitoring themselves, data are generated outside clinical encounters, and alerts may reach clinicians without an agreed route for interpretation. This can reassure patients and encourage engagement, but it can also lead to anxiety, repeated checking, evaluation of false-positive signals, and incidental findings. Access is uneven because device ownership and effective use depend on income, education, digital literacy, and smartphone access. At population scale, even a low alert rate can produce a substantial number of clinical contacts.

This review examines wearable-enabled AF detection from the perspectives of both patients and health systems. It describes the technologies behind wearable alerts, compares detection yield with clinical outcomes, and considers false-positive results, overdiagnosis, anxiety, patient activation, and health care use. It also outlines safeguards for clinically responsible and socially equitable implementation.

2. Materials and Methods

A structured literature search was conducted in PubMed/MEDLINE and supplemented by citation tracking from major clinical guidelines, systematic reviews, and the reference lists of included articles. The final search was performed on June 30, 2026. Searches combined terms related to atrial fibrillation, wearable technologies, and the clinical, psychological, and health-system consequences of arrhythmia detection. Eligible publications were English-language studies in adults assessing diagnostic performance, costs, patient impact, or health-care organization. Pediatric studies, postoperative monitoring, and algorithms without clinical validation were excluded. Selection and data extraction from 29 included publications, verified in PubMed and Crossref, were conducted by the author team.

3. Results

3.1 Profile of the Included Evidence

The 29 publications covered complementary but unequal parts of the pathway from a wearable signal to a health outcome. Large remote consumer cohorts established how often notifications occurred and how frequently AF was found during later or simultaneous ECG monitoring. Randomized and pragmatic screening trials assessed whether repeated single-lead ECG, patch monitoring, smartphone-based screening, or continuous monitoring increased diagnosis and treatment compared with usual care. Other studies examined anxiety, usability, clinical contacts, diagnostic testing, cost-effectiveness, device adoption, and ethical or governance concerns. Table 1 summarizes the studies most directly linking detection with confirmation, treatment, patient outcomes, or health-system consequences.

The evidence was strongest for a consistent intermediate outcome: more intensive or repeated monitoring detects more AF than episodic usual care. Evidence became progressively less certain farther along the pathway. Confirmation rates depended on whether ECG monitoring occurred at the same time as a repeat alert or days later; treatment initiation was more common after screening in several trials; and effects on stroke, mortality, hospitalization, bleeding, quality of life, and anxiety were either neutral, imprecise, or incompletely

measured. This distinction between diagnostic yield and patient benefit guided the interpretation of all included evidence.

The studies also differed in who entered the screening pathway. Consumer cohorts largely recruited owners of compatible devices, whereas several randomized trials selected older adults or people with elevated stroke risk. Supported research programs supplied equipment, training, confirmation, and follow-up, while routine consumer use often lacked an agreed clinical route. These differences limit direct comparison but are themselves clinically important: the same algorithm may have different positive predictive value, psychological effects, and workload consequences when moved from a risk-enriched, supported program to unsupervised use in a low-prevalence population.

3.2 Wearable Technologies and the Meaning of an Alert

PPG infers pulse timing from changes in reflected light caused by peripheral blood flow. Consumer devices analyze sequences of pulse intervals for irregularity and often restrict assessment to periods of limited movement to reduce artifact. Passive PPG is convenient because the user does not need to start a recording. It captures a peripheral pulse signal, however, not atrial electrical activity or P waves. Motion, poor skin contact, ectopic beats, sinus arrhythmia, and other non-AF rhythms can all produce irregular patterns. A PPG notification is therefore a reason to assess the rhythm, not a diagnosis.

Recording a single-lead ECG requires the user to touch an electrode and remain relatively still. An interpretable tracing can document an irregular rhythm more specifically than PPG alone. A consumer ECG is nevertheless shorter and less informative than a standard 12-lead ECG, and automated classifications may be inconclusive or fall outside the validated heart-rate range. Diagnosis still depends on clinical review of an adequate tracing in context.

Early validation studies showed that wearable signals could identify AF under controlled conditions. Tison et al. (2018) trained a deep neural network using smartwatch heart-rate and step-count data. Performance against 12-lead ECG was high in a small external cardioversion cohort, but lower in an ambulatory exploratory cohort that relied on self-reported persistent AF. The difference illustrates how performance may change when an algorithm moves from supervised validation to unsupervised daily use. Meta-analyses have reported high pooled sensitivity and specificity for smartphones and smartwatches, but also substantial heterogeneity in devices, populations, reference standards, and study design (Prasitlumkum et al., 2021; Belani et al., 2021). Such pooled estimates describe test performance under study conditions. They do not establish the positive predictive value of an alert in a young, low-prevalence population, nor do they show that screening prevents stroke.

Timing further complicates the relation between an alert and its confirmation. A PPG notification may coincide with an AF episode, yet a patch applied days later may be negative because the episode has ended. Conversely, a high positive predictive value for a repeat PPG alert recorded during simultaneous ECG monitoring does not imply that every initial notification will be confirmed later. These measurements answer different clinical questions and should not be interpreted interchangeably.

3.3 Evidence From Large Consumer-Device Studies

The Apple Heart Study enrolled 419,297 participants who used their own Apple Watch and iPhone. During a median of 117 days, 0.52% received an irregular-pulse notification. Among 450 participants who returned an analyzable ECG patch, AF was present in 34%; on average, the patch was applied 13 days after the notification. When a subsequent notification occurred during simultaneous ECG monitoring, the positive predictive value for AF was 0.84. Of notified participants who completed the 90-day survey, 57% contacted a health professional outside the study (Perez et al., 2019). Although notifications were uncommon, they often prompted care beyond the research pathway.

The Fitbit Heart Study enrolled 455,699 adults. Irregular heart-rhythm detections occurred in approximately 1% of participants overall and in 4% of those aged 65 years or older. Among 1,057 participants with a notification and an analyzable subsequent ECG patch, AF or atrial flutter was present in 32.2%. When another algorithmic detection occurred concurrently with ECG patch monitoring, the positive predictive value was 98.2% (Lubitz, Faranesh, et al., 2022). These confirmation rates address different circumstances. One reflects AF found during a later week of monitoring; the other reflects a repeat alert recorded at the same time as ECG documentation.

The Huawei Heart Study shows both the scale and the selection effects of consumer-led screening. Among 644,124 users of PPG-enabled Huawei devices, detected AF increased with clinical risk measured by the C2HEST score, and prediction improved when symptoms such as palpitations were included (Guo et al., 2020). The cohort was young on average and predominantly male. Its size did not make it representative of the

older adults most likely to benefit from stroke prevention. Recruiting people at higher clinical risk may yield more relevant diagnoses than screening all device owners indiscriminately.

Two European studies suggest that remote monitoring is feasible in selected older adults. In the Smart in OAC-AFNET 9 case-finding study, participants aged 65 years or older in Germany, Poland, and Spain used a smartphone-linked wristband. Atrial arrhythmias were detected in 5% within four weeks, most often during the first week (Fabritz et al., 2022). A Norwegian self-screening study using a continuous ECG patch reported an 87.3% completion rate, high usability, and AF in 2.2% of participants; 45 people had to be screened to identify one previously unrecognized case (Sandberg et al., 2023). These results demonstrate feasibility among volunteers. They may overestimate uptake in populations with limited connectivity, less digital confidence, cognitive impairment, or fewer financial resources.

Table 1. Selected studies linking wearable or intensive AF detection to confirmation, treatment, patient outcomes, or health-system effects

Study	Population and design	Technology	Main finding relevant to this review
Apple Heart Study Perez et al. (2019)	Prospective remote cohort; 419,297 consumer-device users	Passive smartwatch PPG notification followed by 7-day ECG patch	0.52% received a notification; AF was found in 34% of analyzable delayed patches; PPV was 0.84 when a repeat alert occurred with simultaneous ECG.
Fitbit Heart Study Lubitz, Faranesh, et al. (2022)	Prospective remote study; 455,699 adults	Passive PPG algorithm followed by telehealth and 1-week ECG patch	Notifications occurred in 1% overall; AF/flutter was present in 32.2% of later analyzable patches; PPV for a concurrent repeat detection was 98.2%.
REHEARSE-AF Halcox et al. (2017)	Randomized trial; 1,001 adults aged >=65 years with elevated stroke risk	Twice-weekly single-lead ECG for 12 months	AF was diagnosed in 19 monitored participants versus 5 controls; clinical events did not differ significantly; acceptability was high.
mSToPS Steinhubl et al. (2018)	Randomized immediate-vs-delayed monitoring plus matched cohort analysis	Self-applied continuous ECG patch	Immediate monitoring increased AF detection; monitored participants had more anticoagulant initiation and greater outpatient resource use.
SCREEN-AF Gladstone et al. (2021)	Randomized trial; 856 adults aged >=75 years with hypertension	Two 2-week continuous ECG patches plus oscillometric BP screening	AF was detected in 5.3% versus 0.5%; intermittent BP-device screening had 35% sensitivity and 8.9% PPV.
eBRAVE-AF Rizas et al. (2022)	Pragmatic randomized crossover trial; 5,551 older policyholders	Smartphone pulse-wave screening with 14-day ECG confirmation	Digital screening more than doubled detection of AF that was subsequently treated with oral anticoagulation.
VITAL-AF Lubitz, Atlas, et al. (2022)	Cluster-randomized primary-care trial; 30,715 adults without known AF	Single 30-second handheld ECG during vital-sign assessment	No significant increase in new AF diagnosis overall at 1 year; a larger difference was observed in the oldest subgroup.
STROKESTOP Svennberg et al. (2021)	Population randomized trial; 28,768 adults aged 75-76 years	Invitation to intermittent ECG screening for 14 days	A small reduction occurred in a broad composite clinical endpoint after median 6.9 years; approximately half of invitees participated.
LOOP Svendsen et al. (2021)	Randomized trial; 6,004 high-risk adults aged 70-90 years	Implantable continuous ECG monitoring	AF diagnosis and anticoagulation increased about threefold, without a statistically significant reduction in stroke/systemic embolism.

Study	Population and design	Technology	Main finding relevant to this review
GUARD-AF Lopes et al. (2024)	Randomized primary-care trial; 11,905 adults aged >=70 years	14-day continuous ECG patch	AF diagnosis increased from 3.3% to 5.0%, but stroke hospitalization was not reduced; enrollment ended early during COVID-19.
AMALFI Wijesurendra et al. (2025)	Remote randomized trial; 5,040 adults at moderate-to-high stroke risk	Mailed self-applied 14-day ECG patch	AF recording and anticoagulant exposure increased modestly at 2.5 years; exploratory stroke rates were similar.
Pulsewatch Paul et al. (2023); Ding et al. (2023)	Randomized smartwatch monitoring among older stroke survivors	Smartwatch-smartphone PPG system with ECG-patch comparator	Monitoring did not significantly worsen anxiety or patient activation; accuracy was 92.9%, usability was moderate, and adherence was incomplete.
Routine AF care Rosman et al. (2024)	Propensity-matched observational study; 172 patients with established AF	Commercial wearable use and cardiac alerts	Users reported more symptom preoccupation and treatment concern; 20% reported anxiety and always contacting a physician after alerts.

Note. Numerical results are reproduced from the cited publications; PPG, photoplethysmography; ECG, electrocardiogram; AF, atrial fibrillation; PPV, positive predictive value.

3.4 Randomized Screening Trials: More Diagnoses, Uncertain Clinical Benefit

Randomized trials generally find more AF with longer or repeated monitoring than with routine care. They also show why diagnostic yield alone is an inadequate endpoint. In REHEARSE-AF, 1,001 adults aged at least 65 years with elevated stroke risk were randomized to twice-weekly single-lead ECG recordings or routine care. AF was diagnosed in 19 monitored participants and five controls. Participants generally found the device easy to use and did not report activity restriction or anxiety. Thromboembolic events did not differ significantly, although the trial was not powered for clinical outcomes (Halcox et al., 2017).

The mSToPS trial evaluated a self-applied continuous ECG patch. Immediate monitoring identified AF more often than delayed monitoring at four months. In a matched observational comparison at one year, monitored participants had more AF diagnoses, anticoagulant initiation, cardiology visits, and slightly more primary care visits, without a difference in AF-related emergency visits or hospitalizations (Steinhubl et al., 2018). Increased detection was therefore accompanied by increased treatment and outpatient resource use.

SCREEN-AF enrolled adults aged at least 75 years with hypertension. Two periods of two-week continuous ECG patch monitoring detected AF in 5.3% of the screening group compared with 0.5% of controls, and anticoagulation was initiated in most participants with patch-detected AF. By comparison, intermittent screening with an oscillometric blood-pressure monitor had low sensitivity and a positive predictive value of 8.9% (Gladstone et al., 2021). Both detection and the burden of inconclusive or false-positive results depend on the device and monitoring intensity.

The eBRAVE-AF trial used a smartphone application followed by external ECG confirmation in 5,551 older policyholders. Digital screening more than doubled the detection of AF that was subsequently treated with oral anticoagulation during both crossover phases (Rizas et al., 2022). The study, however, was designed around treatment-relevant detection rather than stroke reduction. VITAL-AF embedded a single 30-second handheld ECG in routine primary-care vital-sign assessment. At one year, it found no significant increase in new AF diagnoses among all participants aged 65 years or older, although a prespecified older subgroup showed a larger difference (Lubitz, Atlas, et al., 2022). The contrast suggests that a single recording in an unselected population is less productive than prolonged or repeated monitoring in people at higher risk.

Evidence for hard clinical outcomes remains uncertain. STROKESTOP invited all 75- to 76-year-old residents in two Swedish regions to intermittent ECG screening. After a median follow-up of 6.9 years, the intervention produced a small reduction in a broad composite of stroke, systemic embolism, bleeding requiring hospitalization, and all-cause death, with a hazard ratio of 0.96 and a confidence interval reaching 1.00

(Svennberg et al., 2021). Only about half of those invited participated, an important consideration when estimating the population effect of a voluntary screening program.

The LOOP trial used an implantable loop recorder rather than a consumer wearable, but it helps clarify the clinical meaning of intensive detection. Continuous monitoring increased AF diagnosis and anticoagulation approximately threefold, yet did not significantly reduce stroke or systemic embolism; major bleeding was numerically more frequent but not statistically different (Svendsen et al., 2021). Short, subclinical episodes found through intensive surveillance may not carry the same treatment value as AF detected in routine clinical practice.

GUARD-AF randomized 11,905 adults aged at least 70 years to a 14-day ECG patch or usual care. Screening increased AF diagnosis from 3.3% to 5.0% and increased anticoagulant initiation, but stroke hospitalization was not reduced. The trial was stopped before reaching its planned sample size because of disruption during the COVID-19 pandemic and consequently had limited power for uncommon events (Lopes et al., 2024). AMALFI subsequently found that a mailed, self-applied 14-day ECG patch produced a modest increase in AF recorded over 2.5 years and increased anticoagulant exposure, but exploratory stroke rates were similar between groups (Wijesurendra et al., 2025).

A recent synthesis included 32 studies and 735,542 participants. Systematic noninvasive screening increased incident AF detection in randomized trials, with a pooled relative risk of 2.22, but did not significantly reduce death, cardiovascular hospitalization, stroke, or bleeding (Wahab et al., 2025). The pattern is consistent: wearable and noninvasive screening finds more AF, but evidence that broad screening improves outcomes important to patients remains limited.

3.5 False-Positive Results, Incidental Findings, and Overdiagnosis

False-positive results and overdiagnosis are often conflated, although they describe different problems. A false-positive alert is one in which the suspected rhythm is not confirmed as AF. Overdiagnosis occurs when genuine AF is detected that would never have caused symptoms or adverse outcomes during the patient's lifetime, yet still leads to labeling, follow-up, or treatment. Wearables can contribute to both.

Wyatt et al. (2020) reviewed 264 people evaluated after an abnormal pulse was detected by Apple Watch. A 12-lead ECG was obtained in 59.8%, ambulatory monitoring in 39.0%, and echocardiography in 22.7%. A clinically actionable cardiovascular diagnosis was established in 11.4%, including AF in 4.9%. The cohort included symptomatic patients and people with pre-existing cardiovascular diagnoses, and documentation did not always distinguish an automated alert from a manually observed pulse value. The study cannot determine a device-specific false-positive rate, but it demonstrates that real-world wearable concerns can trigger extensive diagnostic activity with relatively low yield.

The burden of false-positive results depends heavily on disease prevalence. Even a highly specific test has a lower positive predictive value in younger people with a low baseline probability of AF. Consumer-device studies recruited owners of compatible hardware, producing cohorts that were younger and more technologically engaged than many populations targeted for stroke prevention. Results from simultaneous validation in patients with known AF cannot be transferred directly to population screening.

Overdiagnosis becomes more relevant as monitoring grows more sensitive. AF burden spans a continuum from rare, brief episodes to persistent arrhythmia. LOOP, GUARD-AF, and AMALFI detected more AF and increased anticoagulant use without showing a corresponding reduction in stroke during follow-up (Svendsen et al., 2021; Lopes et al., 2024; Wijesurendra et al., 2025). This does not prove that the additional episodes were harmless. The trials may have been underpowered, follow-up may have been too short, and treatment uptake was incomplete. It does, however, challenge the assumption that every additional AF diagnosis has equal clinical value.

Haase et al. (2026) used randomized screening data to explore possible overdiagnosis and reported substantially increased AF diagnosis and anticoagulation without clear improvement in adverse outcomes. The authors described their analysis as hypothesis-generating rather than a formal systematic review, and their numerical estimates depend on assumptions about which excess diagnoses would never become clinically relevant. They should not be interpreted as definitive prevalence figures. The analysis nonetheless raises a useful question: screening should be judged by the harm it prevents, not simply by the number of diagnoses it produces.

Incidental findings create further difficulty. Single-lead ECG or continuous patches may identify bradycardia, supraventricular tachycardia, ectopy, pauses, or artifact. Some findings require urgent evaluation; others have uncertain significance. Unless a screening program assigns responsibility for review, communication, and escalation, that uncertainty falls on patients and clinicians. Reports should clearly distinguish among a PPG alert, an uninterpretable tracing, a clinician-confirmed AF episode, and an AF diagnosis that leads to a treatment decision.

3.6 Psychological and Behavioral Consequences

Wearable monitoring may reassure patients by providing a sense of control and an objective rhythm record during symptoms. It may also encourage vigilance, repeated checking, and fear of transient abnormalities. The evidence is mixed, partly because prescribed monitoring within a supported study is different from unsupervised use of a consumer device.

In REHEARSE-AF, most participants found intermittent ECG monitoring acceptable and did not report that it caused anxiety or restricted activity (Halcox et al., 2017). The Pulsewatch randomized trial similarly found no significant worsening of anxiety, patient activation, or self-reported physical or mental health among stroke survivors assigned to smartwatch monitoring (Paul et al., 2023). Participants received training and used a defined monitoring protocol, which may have reduced uncertainty. A related Pulsewatch analysis reported 92.9% AF-detection accuracy, moderate usability, and wear on an average of 21.2 of 30 days, indicating that older stroke survivors could use the system but that adherence was incomplete (Ding et al., 2023).

Observations from routine AF care are less reassuring. Rosman et al. (2024) combined survey and electronic-record data from patients with established AF. Wearable users reported more symptom monitoring and preoccupation and greater concern about treatment than nonusers. Twenty percent reported anxiety and said they always contacted a physician after an irregular-rhythm notification. They also used more formal and informal health care. These findings do not establish causality: patients who are already concerned about their rhythm may be more likely to buy and use a wearable. Even so, the study identifies a clinically relevant group in whom monitoring may intensify illness-focused attention.

The contrast between trial and observational findings suggests that psychological effects depend on how monitoring is delivered, not only on the device. Training, expectations, alert wording, access to confirmation, and the speed of professional feedback all shape the response. A notification that explains its uncertainty and gives a clear, non-emergency follow-up route is quite different from an unexplained warning delivered at night without clinical support. Patients should be told that PPG detects irregularity rather than diagnoses AF, that a normal reading does not exclude intermittent AF, and that urgent symptoms require clinical assessment regardless of the device result.

3.7 Health Care Utilization and Economic Consequences

Wearable alerts can bring previously undiagnosed AF to clinical attention, but they also shift work into primary care, emergency services, cardiology, diagnostic laboratories, and patient messaging systems. In the Apple Heart Study, more than half of notified survey respondents contacted a health professional outside the study (Perez et al., 2019). Wyatt et al. (2020) documented frequent ECG, ambulatory monitoring, imaging, and laboratory testing among patients who presented after Apple Watch pulse abnormalities.

In mSToPS, monitored participants had more cardiology and primary-care visits than matched controls, although AF-related emergency visits and hospitalizations were not increased (Steinhubl et al., 2018). Wang et al. (2021) likewise found a higher composite measure of health care use among patients with established AF who used wearables, despite similar measured pulse rates after matching. Ablation was more frequent among wearable users. Residual confounding is likely: younger, more activated, or more symptomatic patients may both adopt technology and pursue rhythm-control care. Nevertheless, these studies show that wearable-generated information is not operationally neutral.

Rosman et al. (2024) extended this observation to informal care, including telephone calls and portal messages. These interactions may not appear in conventional utilization measures, yet they can add substantially to clinician workload. Health systems that accept wearable data need to specify who reviews incoming tracings, how quickly they are addressed, which findings require repeat monitoring, and when a patient should be directed to routine rather than urgent care.

Economic models are more favorable, although their conclusions are conditional. Chen et al. (2022) compared several screening pathways in a simulated US population aged 65 years or older. Strategies combining wearable PPG, wearable ECG, and confirmatory patch monitoring were estimated to be cost-effective at conventional willingness-to-pay thresholds. The model projected fewer strokes but more major bleeding. Its conclusions depend on assumptions about AF prevalence, test performance, anticoagulation uptake, treatment effect in screen-detected AF, device cost, and adherence. Modeling can compare strategies, but it cannot replace trials that demonstrate net clinical benefit.

Targeting people at higher risk may improve efficiency. In the Huawei analysis, clinical risk and symptoms increased the probability of detected AF (Guo et al., 2020). The recent meta-analysis likewise found higher yields when age was combined with risk scores or biomarkers rather than used alone (Wahab et al., 2025). A clinically directed program would prioritize people with meaningful stroke risk and a reasonable probability of AF instead of treating universal consumer monitoring as population screening.

3.8 Equity, Ethics, and Data Governance

Consumer-led screening may widen health inequalities. A US national survey found that fewer than one-third of adults used wearable health devices, with adoption concentrated among younger, wealthier, more educated, and more technologically confident respondents (Chandrasekaran et al., 2020). Many older adults at highest risk of AF-related stroke do not share those characteristics. When screening depends on owning a compatible smartwatch and smartphone, access may follow purchasing power rather than clinical need.

Algorithm performance also depends on who was represented in validation studies. The Fitbit Heart Study population was 73% White, and the Pulsewatch cohort was predominantly White (Lubitz, Faranesh, et al., 2022; Ding et al., 2023). The Huawei cohort was large but young and predominantly male (Guo et al., 2020). Skin characteristics, perfusion, movement patterns, comorbidity, and patterns of device use may all affect PPG signal quality in practice. Performance should be reported across demographic and clinical subgroups rather than assumed to be uniform.

Predel and Steger (2020) identified concerns involving non-maleficence, autonomy, justice, privacy, commercial influence, and the physician-patient relationship. Consumer products may encourage patients to take part in their care, but meaningful autonomy requires clear information about uncertainty, downstream consequences, and data use. Users may not realize that wellness-device data can be stored by commercial entities, transferred across jurisdictions, or used for purposes beyond direct care.

Digital studies show that remote pathways can work for older adults, including in European settings (Fabritz et al., 2022; Sandberg et al., 2023). Feasibility among volunteers, however, is not evidence of equitable access. A fair program would offer loaned or prescribed devices to clinically eligible patients, non-digital alternatives, accessible training, technical support, and information in appropriate languages. Data minimization, transparent consent, secure transfer, defined retention periods, and clear accountability for algorithm updates are clinical requirements, not optional technical details.

4. Discussion

4.1 Principal Findings

Four findings emerge from this synthesis. First, technical performance cannot be interpreted independently of prevalence, timing, and the confirmatory pathway. The high positive predictive value of a repeat alert recorded during simultaneous ECG monitoring answers a different question from the proportion of people in whom AF is found on a patch applied days after an initial notification. A negative delayed patch may miss a transient episode, while a positive consumer alert in a low-risk user may still have a low probability of representing clinically important AF (Perez et al., 2019; Lubitz, Faranesh, et al., 2022). Reporting a single accuracy value without this context can therefore mislead both patients and clinicians.

Second, an increase in diagnosis is not equivalent to an improvement in health. REHEARSE-AF, SCREEN-AF, eBRAVE-AF, mSToPS, LOOP, GUARD-AF, and AMALFI used different populations and technologies, but collectively show that monitoring can increase AF detection and often anticoagulant exposure. With the partial exception of the small composite effect in STROKESTOP, the larger body of randomized evidence has not established consistent reductions in stroke, mortality, or hospitalization (Halcox et al., 2017; Steinhubl et al., 2018; Gladstone et al., 2021; Svennberg et al., 2021; Svendsen et al., 2021; Rizas et al., 2022; Lopes et al., 2024; Wijesurendra et al., 2025; Wahab et al., 2025). This gap may reflect insufficient power, incomplete participation, limited follow-up, or lower prognostic importance of some screen-detected episodes. It nevertheless argues against using the number of alerts or diagnoses as the sole measure of success.

Third, the psychological effect is shaped by service design. Participants given training, a defined monitoring schedule, and access to confirmation generally tolerated monitoring well, whereas routine wearable users with established AF described more preoccupation, treatment concern, and clinician contact (Halcox et al., 2017; Paul et al., 2023; Rosman et al., 2024). These findings are not contradictory. They suggest that uncertainty, repeated checking, and the absence of a follow-up route may be more harmful than monitoring itself. Alert wording, education, response time, and permission to stop monitoring are therefore active components of a digital intervention.

Fourth, wearable screening redistributes work and opportunity. Some alerts identify actionable disease, but evaluation may also require primary-care review, ECG, ambulatory monitoring, imaging, specialist consultation, telephone calls, and portal messages (Steinhubl et al., 2018; Wyatt et al., 2020; Wang et al., 2021; Rosman et al., 2024). At the same time, consumer ownership is socially patterned, so a pathway based on personal purchase may direct screening toward younger and more affluent users rather than toward those with the greatest stroke risk (Chandrasekaran et al., 2020). Clinical effectiveness, workload, and distributive fairness must therefore be evaluated together.

4.2 A Clinically Responsible Pathway for Wearable AF Alerts

Wearable alerts require a staged clinical pathway; they should not function as autonomous consumer diagnoses.

Monitoring should begin with a clear clinical question. Screening an asymptomatic person without known AF is different from documenting symptoms, assessing recurrence after treatment, or estimating AF burden in someone with an established diagnosis. The alert threshold and follow-up plan should match that purpose.

Interpretation should then be anchored in baseline risk. Age, symptoms, cardiovascular comorbidity, previous stroke, and thromboembolic risk influence both the probability that an alert represents AF and the likely benefit of treatment. Screening yield is generally higher in risk-enriched groups than in unselected device owners (Guo et al., 2020; Wahab et al., 2025).

Whatever the indication, a PPG alert should lead to confirmatory ECG rather than direct labeling or anticoagulation. If a consumer device records a readable single-lead ECG during symptoms or an alert, a qualified clinician should review the tracing. When no diagnostic tracing is available, external ECG monitoring can be selected according to symptom frequency and clinical risk. A negative patch applied later does not necessarily prove that the original alert was false, but treatment should not be started on the basis of PPG alone.

Communication is part of the intervention. Written information should distinguish emergency symptoms from situations suitable for routine follow-up, explain artifact and intermittent arrhythmia, and discourage repeated unscheduled measurements that will not change management. A monitoring plan should state how long to record, when to stop, and whom to contact.

Treatment decisions should take account of the confirmed rhythm, AF burden and context, thromboembolic and bleeding risk, patient preferences, and current clinical guidance. More detection is not evidence of benefit in itself, as illustrated by LOOP, GUARD-AF, AMALFI, and the recent meta-analysis (Svendsen et al., 2021; Lopes et al., 2024; Wijesurendra et al., 2025; Wahab et al., 2025).

Implementation also needs to be audited. Useful measures include the proportion of alerts with analyzable ECG confirmation, time to clinical review, AF yield, additional testing, anticoagulant initiation, bleeding, emergency visits, patient anxiety, portal workload, and disparities in access. A program can be technically accurate and still provide poor value if these consequences are ignored.

4.3 Implications for Health Services and Policy

Health services should decide in advance what happens when a consumer-generated alert enters a clinical system. A minimum pathway needs an identifiable point of contact, a distinction between emergency symptoms and routine review, a route to obtain an interpretable ECG, a target time for assessment, and a clear record of who communicates the result. Without these elements, the device creates a task without assigning responsibility. The resulting delays, duplicate testing, or defensive referral may be wrongly attributed to the technology rather than to the absence of service design.

Procurement and governance decisions should extend beyond headline sensitivity or specificity. Relevant questions include whether performance has been evaluated in the population that will use the device, how uninterpretable recordings are handled, whether algorithm versions are traceable, how updates are communicated, where data are stored, who can access them, and whether the output can enter the clinical record without unnecessary duplication. Commercial convenience does not remove professional accountability for diagnosis or treatment (Predel & Steger, 2020; Joglar et al., 2024).

Evaluation should count the full consequences of the pathway. In addition to AF yield and anticoagulant initiation, services should measure time to confirmation, bleeding, stroke, emergency presentations, repeat testing, specialist referrals, message volume, professional review time, patient anxiety, and withdrawal from monitoring. Economic models suggest that selected wearable pathways may be cost-effective, but their conclusions remain sensitive to assumptions about treatment benefit, adherence, device cost, and bleeding (Chen et al., 2022). Local implementation data are therefore needed before a model result is treated as a budget forecast.

Equity requires an alternative to consumer ownership. Risk-based programs can provide loaned devices, assisted setup, language-appropriate instructions, telephone or face-to-face routes, and support for people with sensory, cognitive, or digital limitations. Uptake, technical failure, confirmation, and outcomes should be reported across relevant demographic and socioeconomic groups. Otherwise, a program may appear efficient among successful users while silently excluding the people least able to enter or complete the pathway (Chandrasekaran et al., 2020; Fabritz et al., 2022; Sandberg et al., 2023).

4.4 Priorities for Future Research

Future trials should compare clinically defined strategies rather than devices in isolation. Useful comparisons include risk-targeted screening versus unselected screening, supported monitoring versus an unsupported alert, and different confirmation or communication pathways after the same signal. Eligibility criteria, monitoring intensity, clinician involvement, and the content of usual care should be reported precisely. This would help distinguish the effect of the sensor from the effect of education, access to ECG confirmation, and professional follow-up.

Outcome reporting should follow the complete screening cascade: people eligible, invited, enrolled, actively monitored, alerted, successfully contacted, able to provide an analyzable tracing, confirmed with AF, offered treatment, treated, and followed for clinical outcomes. Time from alert to confirmation and the proportion lost at each stage are particularly important. A pathway can have excellent concurrent algorithm performance yet poor population value if few people complete confirmation or if those who do are not the group most likely to benefit.

Trials also need outcomes that matter to patients and services. Stroke, systemic embolism, major bleeding, hospitalization, mortality, quality of life, reassurance, anxiety, repeated checking, treatment burden, and decisional conflict should be measured prospectively. Health-system evaluation should include portal messages, telephone contacts, clinician review time, repeat monitoring, incidental findings, and downstream procedures, not only emergency visits or admissions. Baseline psychological measures would help separate effects caused by monitoring from the pre-existing tendency of more concerned patients to adopt wearables (Rosman et al., 2024).

Longer follow-up is necessary to determine whether early increases in diagnosis produce durable net benefit and whether engagement persists after research support ends. Studies should prespecify how AF burden and episode duration will be interpreted and should report treatment decisions rather than assuming that every confirmed episode has the same clinical meaning. This is especially important after LOOP, GUARD-AF, and AMALFI, where increased detection and anticoagulant exposure did not translate into a clear reduction in stroke during the reported follow-up (Svendsen et al., 2021; Lopes et al., 2024; Wijesurendra et al., 2025).

Finally, algorithm and equity research should accompany clinical trials. Performance and rates of uninterpretable data should be reported across age, sex, relevant demographic groups, comorbidity, and patterns of real-world use. Investigators should record the hardware and software version, disclose material algorithm changes, and evaluate whether assisted or loaned-device models reduce exclusion. Economic analyses should use observed participation, adherence, professional workload, and treatment effects whenever possible rather than assuming that all notified users move smoothly through the same pathway.

4.5 Strengths and Limitations

A strength of this review is its outcome hierarchy. It separates signal detection from ECG confirmation, diagnosis, treatment, and patient-important outcomes, and it distinguishes a false-positive alert from overdiagnosis of genuine but potentially low-value disease. It also integrates clinical trials with psychological, utilization, economic, ethical, and equity evidence that is often discussed in separate literatures. Bibliographic identifiers and the numerical claims retained in the synthesis were checked against source records.

The studies were heterogeneous. They used passive PPG, user-initiated ECG, handheld ECG, prescribed patches, smartphone cameras, and implantable monitors. Populations ranged from young consumer-device owners to adults in their eighties with hypertension or previous stroke. AF definitions, episode-duration thresholds, confirmatory pathways, and follow-up periods also varied substantially. Diagnostic accuracy in selected validation cohorts cannot be compared directly with notification yield in population studies.

Device manufacturers were involved in many large technology studies, and several screening trials received industry support or equipment. This does not invalidate the findings, but it increases the importance of transparent reporting on protocol design, algorithm changes, missing data, and conflicts of interest. Rapid software updates also limit the shelf life of evidence: findings for one model or algorithm version may not apply to its successor.

Evidence on psychological and behavioral outcomes remains limited. The randomized studies were relatively small, often included substantial training, and may not reflect the experience of an unsupported consumer. Observational studies remain vulnerable to self-selection and confounding. Future trials should measure anxiety, reassurance, repeated checking, and informal clinician workload prospectively.

This review has important methodological limitations. PubMed/MEDLINE was the only bibliographic database searched systematically; citation and guideline tracking may not identify studies indexed only elsewhere. Screening and extraction were not independently duplicated, a protocol was not registered, a

complete study-flow count was not retained, and no new formal risk-of-bias or certainty assessment was performed. The inclusion of English-language publications may also have introduced language bias. For these reasons, the article does not claim systematic-review status and relies on existing meta-analyses for pooled estimates. Its conclusions should be read as a critical narrative synthesis whose main contribution is to connect detection evidence with psychological, utilization, ethical, and equity consequences.

5. Conclusions

Wearable technologies can detect pulse irregularity on a scale that episodic clinical assessment cannot match. Large consumer studies show that notifications are uncommon and sometimes identify previously unrecognized AF. Randomized trials likewise find that repeated or prolonged monitoring detects more AF than usual care and often increases anticoagulant initiation. Whether broad screening reduces stroke, mortality, or hospitalization is much less certain.

The consequences extend well beyond diagnostic accuracy. Alerts may lead to anxiety, symptom preoccupation, portal messages, specialist visits, ambulatory monitoring, imaging, procedures, and treatment of episodes whose prognostic importance is uncertain. Programs that provide education and a defined follow-up route appear less psychologically disruptive than unsupported consumer use. Reliance on personally purchased devices, however, risks excluding older, lower-income, and less digitally confident patients.

The appropriate role of a wearable alert is to begin a structured evaluation, not to complete it. PPG findings require ECG confirmation. Screening should be guided by clinical risk, and treatment should reflect episode context, stroke and bleeding risk, and patient preferences. Programs should measure psychological, utilization, and equity outcomes alongside AF detection. Success should be judged not by alert volume, but by the proportion of clinically important cases that receive timely, equitable, evidence-based care.

Authors' contribution statement:

Radosław Sciepuro (35%): Conceptualization; Methodology; Investigation; Data Curation; Writing - Original Draft; Writing - Review & Editing. Dawid Cyls (35%): Validation; critical review of evidence interpretation and textual coherence; Writing - Review & Editing. Marta Czarnowska (15%): Investigation; source analysis; substantive review; Writing - Review & Editing. Nina Czarnowska (15%): Validation; bibliography verification; editorial review; Writing - Review & Editing.

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