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THE USE OF SMARTWATCH DEVICES IN SCREENING FOR CARDIAC ARRHYTHMIAS: A NARRATIVE REVIEW OF CURRENT CAPABILITIES AND LIMITATIONS

Aleksandra Gralec *(Corresponding Author, Email: ola.gral@onet.pl)*
Medical University of Silesia, Katowice, Poland
ORCID ID: 0009-0001-0061-311X

Piotr Helbin
Medical University of Silesia, Katowice, Poland
ORCID ID: 0009-0007-5289-2521

Katarzyna Szlachetka
Medical University of Silesia, Katowice, Poland
ORCID ID: 0009-0006-8012-4805

Piotr Tryczyński
Medical University of Silesia, Katowice, Poland
ORCID ID: 0009-0001-8997-3225

Jakub Wrona
Medical University of Silesia, Katowice, Poland
ORCID ID: 0009-0005-7722-7507

Jakub Sałak
Medical University of Silesia, Katowice, Poland
ORCID ID: 0009-0005-7078-6402

Wiktoria Donocik
Medical University of Silesia, Katowice, Poland
ORCID ID: 0009-0003-3801-6729

ABSTRACT

Background: Atrial fibrillation (AF) is a major stroke risk, yet its asymptomatic nature complicates early detection. While smartwatches using photoplethysmography (PPG) and electrocardiogram (ECG) sensors offer continuous monitoring, their mass adoption introduces profound socio-technological and psychological challenges.
Objective: This review evaluates the diagnostic accuracy of consumer wearables against clinical standards, specifically emphasizing their broader societal impacts, including digital health inequity, algorithmic bias, and technology-induced health anxiety.
Methods: We analyzed literature from PubMed and Google Scholar (2007–2026), reviewing major population trials (e.g., Apple, Huawei, and Fitbit Heart Studies) alongside current guidelines from major cardiovascular societies (ESC, EHRA).
Results: Although resting PPG sensors demonstrate high sensitivity (>90%) and specificity (>95%) for AF detection, real-world accuracy frequently decreases due to motion artifacts, advanced age, and darker skin tones. This algorithmic bias creates a tangible risk of digital health exclusion. Furthermore, continuous biometric tracking often triggers "cyberchondria" and burdens healthcare systems with asymptomatic, low-risk patients (the "worried well"). Additionally, industry-funded trials may overstate clinical benefits to drive commercial sales.
Conclusion: Smartwatches represent a significant advancement in preventative healthcare. However, due to inherent demographic biases and psychological risks, they must serve strictly as preliminary screening tools rather than definitive diagnostics. Prioritizing digital equity, patient well-being, and independent physician oversight is crucial for integrating these devices safely into modern society.

KEYWORDS

Atrial Fibrillation, Wearable Technology, Smartwatch, Photoplethysmography (PPG), Arrhythmia Detection, Cyberchondria, mHealth

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1. Introduction

Atrial fibrillation (AF) is a leading cause of stroke, but its often asymptomatic nature makes it notoriously difficult to detect using traditional, short-term tools like standard ECGs or Holter monitors (Hindricks et al., 2021; Perez et al., 2019). Recently, consumer smartwatches equipped with photoplethysmography (PPG) and single-lead ECGs have disrupted this diagnostic landscape, enabling continuous, long-term heart monitoring outside the clinic (Allen, 2007; Kotecha et al., 2018; Turakhia et al., 2019).

While large-scale trials, such as the Apple, Huawei, and Fitbit Heart Studies, prove that wearable screening is logistically feasible (Guo et al., 2019; Lubitz et al., 2022), these industry-funded projects raise valid ethical concerns. Because positive clinical results directly boost corporate profits, this sponsorship can blur the line between objective medical research and commercial interest (Piwek et al., 2016).

Furthermore, the democratization of health data is a complex sociological phenomenon. Shifting continuous biometric surveillance from the hospital to the user's wrist fundamentally alters how society perceives health and medical authority. The constant flow of Patient-Generated Health Data (PGHD) frequently triggers technology-induced health anxiety (Rosman et al., 2020) and introduces new ethical challenges, including algorithmic bias.

Therefore, this paper aims to move beyond standard clinical evaluations to critically analyze the societal impact of smartwatch technology. By exploring "cyberchondria," digital health inequity, and the systemic burden of overdiagnosis, this review provides a socially-grounded perspective on integrating consumer electronics into modern healthcare.

2. Methodology

To evaluate the diagnostic value of consumer wearables for detecting atrial fibrillation (AF), we conducted a narrative literature review. We searched PubMed, Scopus, and Google Scholar for peer-reviewed articles published between January 2007 to February 2026. Our search terms included "smartwatch," "wearable devices," "atrial fibrillation," "screening," "photoplethysmography (PPG)," and "mobile health (mHealth)." Alongside clinical studies, we reviewed current practice guidelines from the European Society of Cardiology (ESC) and the American Heart Association (AHA) (Hindricks et al., 2021). Studies focusing solely on basic fitness trackers without advanced heart rhythm analysis capabilities were excluded from this review.

3. Technological Foundations of Rhythm Detection (Mechanisms of Action)

Modern smartwatches employ a two-tier diagnostic system that fundamentally shifts health monitoring from the clinic directly to the consumer. The primary method is optical photoplethysmography (PPG), which allows for the continuous, passive tracking of a user’s pulse to identify preliminary rhythm irregularities in everyday settings (Allen, 2007).

If an anomaly is flagged, users can actively generate a miniaturized electrocardiogram (ECG) simply by placing a finger on the device's digital crown. This action closes an electrical circuit across the body, empowering the patient to instantly capture their own cardiac telemetry. Ultimately, integrating passive PPG screening with active, user-initiated ECG confirmation creates a decentralized clinical triage system. It allows ordinary individuals to generate actionable medical data outside the hospital, though this system still strictly relies on a physician to make the formal diagnosis (Bumgarner et al., 2018; Sana et al., 2020).

3.1. Photoplethysmography (PPG): Utilizing Optical Sensors for Pulse Waveform Analysis

Photoplethysmography (PPG) is a non-invasive optical technique that utilizes light-emitting diodes (LEDs) and matched photodetectors to continuously measure changes in blood volume within the peripheral microcirculation (Allen, 2007).

Modern consumer smartwatches, including those developed by Apple, Garmin, and Fitbit, typically employ green light (wavelengths around 530 nm) to monitor heart rate during physical activity. The primary physiological reason for selecting this specific spectrum is its limited penetration depth into the skin.

Interestingly, keeping the light confined to the shallower layers of the dermis helps protect the PPG signal from movement artifacts. This offers a major advantage over red or infrared light, which penetrates deeper into the tissue and is generally reserved for stationary clinical pulse oximetry or for tracking the user's heart rate during sleep (Sana et al., 2020). Since smartwatches are worn continuously during everyday movements and exercise, focusing the measurement on the superficial capillaries successfully avoids the heavy mechanical noise caused by moving muscles and tendons deeper in the wrist (Tamura et al., 2014).

Instead of simply calculating an average heart rate, modern atrial fibrillation (AF) screening algorithms analyze the beat-to-beat variability over time. The software achieves this by generating a virtual tachogram, which is essentially a digital graph mapping the time intervals between consecutive pulses.

A normal sinus rhythm presents with highly regular intervals between beats, showing only minor, natural physiological variations. In contrast, an episode of AF produces a distinctly chaotic and "irregularly irregular" pattern of pulse intervals. When the smartwatch's software detects that these irregular intervals cross a specific diagnostic threshold, it automatically sends a notification to the user, prompting them to seek further medical evaluation (Perez et al., 2019). This automated screening process is illustrated in Figure 1.

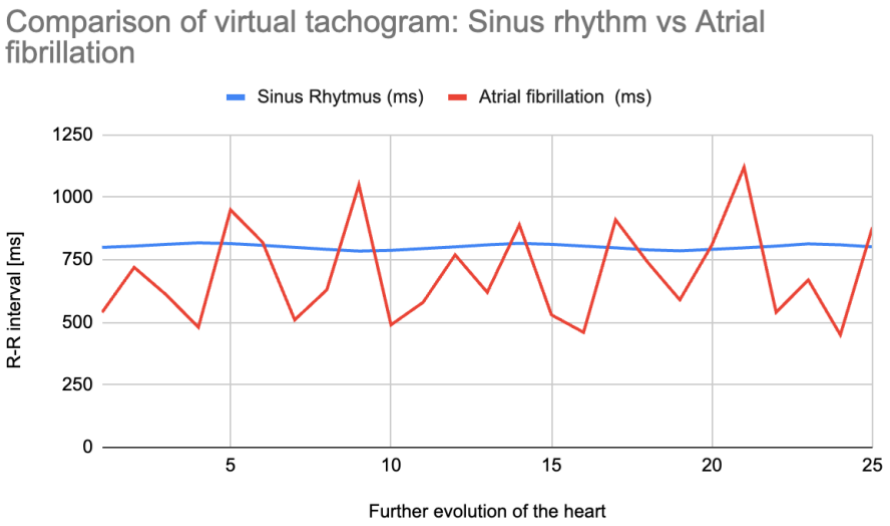

Fig. 1. *Comparison of virtual tachograms illustrating normal sinus rhythm and an episode of atrial fibrillation (AF). The graph depicts the beat-to-beat variability of time intervals between consecutive pulse waves, measured in milliseconds. Source: Authors' own elaboration.*

3.2. Mobile ECG (mECG): Single-Lead Acquisition of Electrical Potentials (Requiring Digital Crown/Bezel Contact)

Complementing passive optical screening, the mobile electrocardiogram (mECG) requires active user engagement. To capture the heart's true electrical activity, the user must deliberately interact with the smartwatch by touching its digital crown, which completes a bipolar electrical circuit across their body (Samol et al., 2019; Sana et al., 2020).

This physical interaction generates a 30-second electrical tracing that is instantly analyzed by the device's built-in Software as a Medical Device (SaMD). The algorithm categorizes the rhythm into straightforward digital outputs such as normal sinus rhythm, atrial fibrillation, or an "inconclusive" reading, which is most frequently caused by simple user movement or muscle tremors.

Clinical validations, including a landmark study by Bumgarner et al. (2018), confirm the remarkable accuracy of this consumer technology, reporting 98.3% sensitivity and 99.6% specificity for detecting atrial

fibrillation. However, from a socio-technical perspective, the true significance of the mECG lies in patient empowerment. By allowing ordinary individuals to actively capture clinical-grade telemetry on demand, the smartwatch fundamentally democratizes cardiac monitoring. Yet, this democratization also introduces new systemic challenges, as users must now independently navigate complex biometric data and frequent "inconclusive" alerts that were previously the exclusive domain of medical professionals.

3.3. The Role of Artificial Intelligence (AI): Machine Learning Algorithms in Signal Interpretation and Noise Reduction

The raw physiological data captured by wearable sensors is inherently noisy, frequently disrupted by everyday physical movements or poor device fit. To prevent this mechanical noise from triggering false-positive alerts, which can cause significant psychological distress for the user - artificial intelligence (AI) and machine learning (ML) act as crucial digital gatekeepers. Algorithms continuously calculate a Signal Quality Index (SQI), automatically discarding unreadable data segments to shield patients from unnecessary medical panic (Tison et al., 2018).

Modern smartwatches have evolved beyond simple programming rules, increasingly relying on Convolutional Neural Networks (CNNs) trained via supervised learning. By analyzing massive "Big Data" repositories of expert-labeled ECG strips, these complex models learn to identify subtle arrhythmic patterns autonomously (Attia et al., 2019).

A landmark study by Hannun et al. (2019) demonstrated that deep neural networks can detect arrhythmias with an accuracy that matches, and sometimes exceeds, that of board-certified cardiologists. From a socio-technical perspective, this represents a profound paradigm shift: the diagnostic authority traditionally held exclusively by human experts is increasingly being delegated to automated algorithms residing on consumer wrists.

4. Screening for Atrial Fibrillation (AF)

Atrial fibrillation (AF) is currently the most common sustained heart rhythm disorder affecting roughly 2% to 4% of the adult population in Europe. As our demographic continues to age, the number of people diagnosed with this condition is steadily rising (Hindricks et al., 2021). Clinically speaking, the greatest danger of AF is not the irregular heartbeat itself, but the severe risk of thromboembolic complications. When the upper chambers of the heart fail to contract properly, blood tends to pool and stagnate particularly within the left atrial appendage creating an ideal environment for clot formation.

If these blood clots break loose and travel into the brain's circulation, they cause ischemic strokes. Strokes triggered by AF are notoriously dangerous, they usually present with a much more severe clinical course and carry significantly higher mortality rates than strokes from other causes (Freedman et al., 2016; Hindricks et al., 2021).

One of the biggest hurdles in preventive cardiology is that a large segment of patients, perhaps as many as 30% to 40%, do not feel any symptoms at all. In traditional medical practice, this "silent AF" often goes completely unnoticed until the patient suffers their first stroke. This represents a massive missed opportunity for early, preventative care. Standard diagnostic tools like a quick 12-lead ECG in the clinic or a 24-hour Holter monitor only look at the heart for a very limited window of time. Because of this, they frequently miss paroxysmal AF, where the irregular rhythm only happens sporadically (Freedman et al., 2016). This is exactly where wearable technologies step in, offering a completely new approach to long-term, continuous heart monitoring. Because smartwatches are so widely used and can passively track a user's pulse for months on end, they have a unique ability to fill the diagnostic gaps between standard doctor visits.

By providing this ongoing surveillance, wearables can catch AF in its early, silent stages. This gives physicians the crucial time needed to start oral anticoagulant (OAC) therapy potentially preventing a devastating stroke before it strikes (Svennberg et al., 2022). The next section will take a closer look at the actual clinical evidence to see how well this modern approach works in the real world.

4.1. Pivotal Clinical Trials: The Apple Heart Study, Huawei Heart Study, and Fitbit Heart Study

The diagnostic utility of consumer wearables was established through massive, industry-sponsored population studies—most notably the Apple, Huawei, and Fitbit Heart Studies. Collectively enrolling over a million subjects, these initiatives pioneered a completely "site-less," decentralized model of medical research. In the landmark Apple Heart Study (AHS), the entire clinical pathway, spanning from initial enrollment to

continuous monitoring and remote telemedicine confirmation—was executed entirely outside the confines of traditional healthcare facilities (Perez et al., 2019; Turakhia et al., 2019).

However, from a sociological perspective, the AHS revealed a critical demographic paradox inherent in consumer health technology. Out of nearly 420,000 participants, only 0.52% received an irregular rhythm notification.

Age-based stratification highlighted a stark contrast: the notification rate was a mere 0.16% for users under 40, but surged to 3.1% for those over 65 (Perez et al., 2019). As visually detailed in Figure 2, this data perfectly mirrors the natural clinical progression of atrial fibrillation. More importantly, it exposes a profound digital health inequity: the individuals most likely to own expensive consumer wearables (younger, healthier demographics) are the least likely to benefit from continuous arrhythmia screening, whereas the high-risk elderly population remains largely digitally excluded.

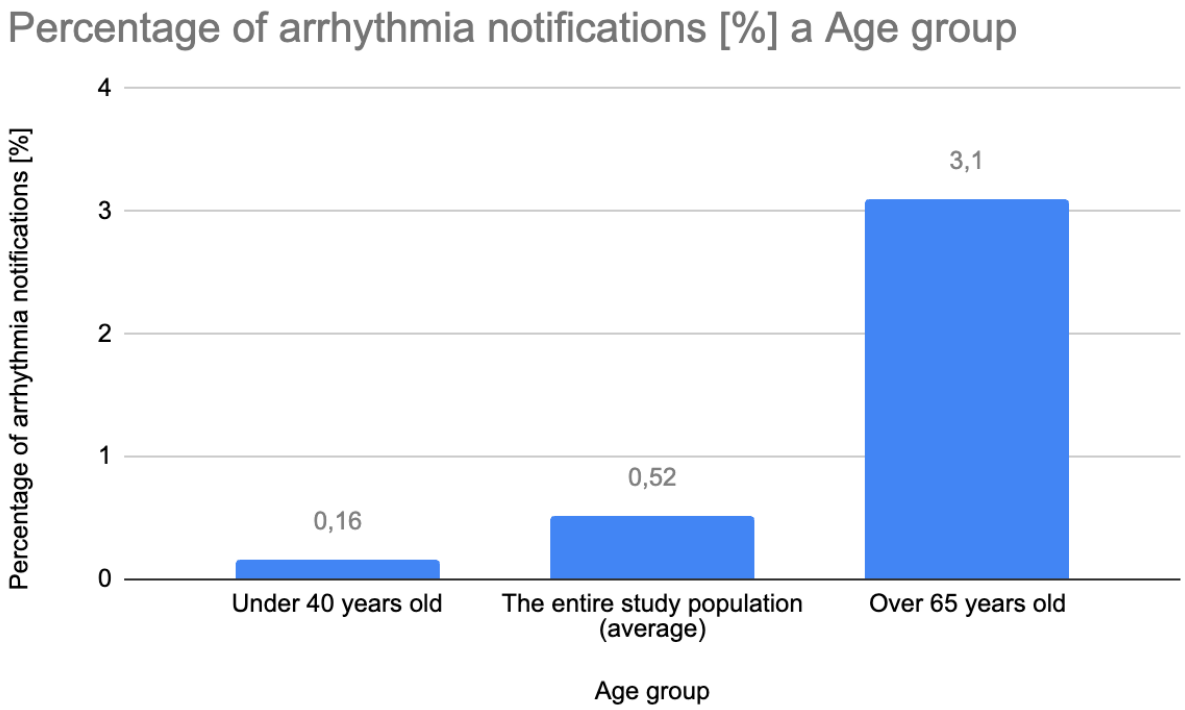

Fig. 2. *The relationship between patient age groups and the frequency of clinically relevant irregular rhythm notifications during the Apple Heart Study. The dramatic rise in alert rates among older adults - specifically those over 65 years of age strongly aligns with our current clinical understanding of atrial fibrillation, confirming that the risk of developing this arrhythmia naturally increases as patients grow older. Source: Original figure created by the author, based on clinical data provided by Perez et al. (2019).*

The logistical challenges of decentralized screening were evident in the Apple Heart Study. Because the trial relied on mailing physical ECG patches to users after an alert, transient arrhythmias often resolved naturally before the monitor arrived, lowering the overall clinical confirmation rate (Perez et al., 2019).

In contrast, the Huawei Heart Study pioneered a comprehensive mobile health (mHealth) ecosystem. By digitally tethering the wearable screening app to a vast network of partner hospitals, the smartwatch functioned as a "digital front door" to the traditional healthcare system. This immediate, app-based referral pathway dramatically shortened diagnostic delays, achieving a remarkable 87% positive predictive value (PPV) (Guo et al., 2019, 2020).

The subsequent Fitbit Heart Study further refined this systemic integration by fundamentally altering its software logic. By requiring continuous pulse irregularity across "overlapping tachogram windows" (specifically, 11 out of 30 consecutive minutes) before triggering an alert, the algorithm achieved a staggering 98% PPV (Lubitz et al., 2022).

From a socio-technical standpoint, this algorithmic evolution is critical. High specificity proves that software can be deliberately calibrated to protect users from technology-induced anxiety while simultaneously

ensuring that traditional clinics and hospitals are not overwhelmed by healthy 'worried well' patients seeking unnecessary validation. A complete summary of these landmark trials is detailed in Table 1.

Table 1. (Guo et al., 2019; Lubitz et al., 2022; Perez et al., 2019).

Characteristic / Parameter	Apple Heart Study (AHS) [1]	Huawei Heart Study (HHS) [2]	Fitbit Heart Study (FHS) [3]
Number of participants (n)	419 297	187 912	455 699
Device	Apple Watch (Series 1–3)	Huawei / Honor	Fitbit
Detection algorithm	Tachogram (5 out of 6 positive cycles)	PPG analysis + MAFA Cloud	Overlapping windows (11 of 30 min)
Notification rate	0,52%	0,23%	1,0%
Verification method	Mailed ECG patch	Holter / 12-lead ECG (in-hospital)	Mailed ECG patch
Positive Predictive Value (PPV)	84% (simultaneous concordance)	87% (clinical confirmation)	98% (clinical confirmation)
Main limitation	Low return rate of ECG patches	Hospital visit required	No data on treatment initiation

4.2. Comparing Smartwatch Algorithm Performance Against the "Gold Standard" (12-Lead ECG and Holter Monitoring)

To legitimize consumer wearables as diagnostic tools, they must be rigorously tested against traditional clinical benchmarks, namely the 12-lead ECG and Holter monitors. Controlled, hospital-based studies, such as the WATCH-AF trial (Dörr et al., 2019) and research by Bumgarner et al. (2018), confirm that under ideal, resting conditions, smartwatches achieve remarkable precision. Passive optical (PPG) sensors demonstrate over 93% sensitivity and 98% specificity, while actively recorded smartwatch ECGs reach near-perfect accuracy (98.3% sensitivity and 99.6% specificity).

While these impressive metrics rival professional hospital equipment, they expose a crucial socio-behavioral trade-off. The highly accurate active ECG relies entirely on patient compliance, requiring the user to recognize symptoms and deliberately initiate a recording. Consequently, this active method is fundamentally flawed for detecting asymptomatic or "silent" arrhythmias. Ultimately, while traditional monitors remain the absolute gold standard for complex electrophysiology, smartwatches fundamentally disrupt the medical paradigm by trading absolute morphological detail for unprecedented, continuous, real-world surveillance (Svennberg et al., 2022).

5. Detecting Alternative Arrhythmias and Conduction Abnormalities

While regulatory bodies like the FDA and the European CE mark currently approve smartwatch electrocardiograms primarily for atrial fibrillation (AF), the true potential of these wearables extends far beyond a single condition. The primary bottleneck limiting broader application is not the physical hardware, but the restrictive commercial software. Algorithms engineered by technology giants rely on rigid binary logic, trained almost exclusively to hunt for the specific electrophysiological signatures of AF.

Consequently, this narrow focus creates a massive diagnostic blind spot. A wide spectrum of alternative cardiac rhythms including conduction blocks, extreme heart rates, and artificially paced rhythms are frequently misinterpreted or simply dismissed by the software as "unclassified" (Isakadze & Martin, 2020).

From a socio-technical perspective, this algorithmic narrowing is highly problematic. It leaves users with ambiguous health data, frequently generating anxiety rather than actionable clarity. Expanding the

diagnostic scope of these algorithms is therefore not merely a clinical challenge; it is a vital step toward creating more comprehensive, patient-centered digital health tools that accurately reflect the complex realities of human physiology.

5.1. Premature Contractions (PVCs and PACs): Opportunities and Challenges in Rhythm Differentiation

Premature atrial and ventricular contractions (PACs and PVCs) are highly common, benign rhythm disturbances frequently triggered by everyday human experiences, such as acute stress or caffeine consumption. Despite being completely normal, these physiological quirks present a substantial obstacle for wearable algorithms, acting as a leading source of inaccurate false-positive atrial fibrillation (AF) warnings (Isakadze & Martin, 2020).

When an ectopic beat occurs, it is typically followed by a brief, natural delay known as a compensatory pause.

As illustrated in Figure 3, the rigid, binary logic of smartwatch software frequently misinterprets this momentary shift in pulse timing as the chaotic, "irregularly irregular" pattern of AF (Duncker et al., 2021). From a socio-technical perspective, this algorithmic inflexibility is highly problematic. It essentially pathologizes normal human biology, transforming harmless physiological quirks into unwarranted medical alarms that generate unnecessary health anxiety for the consumer.

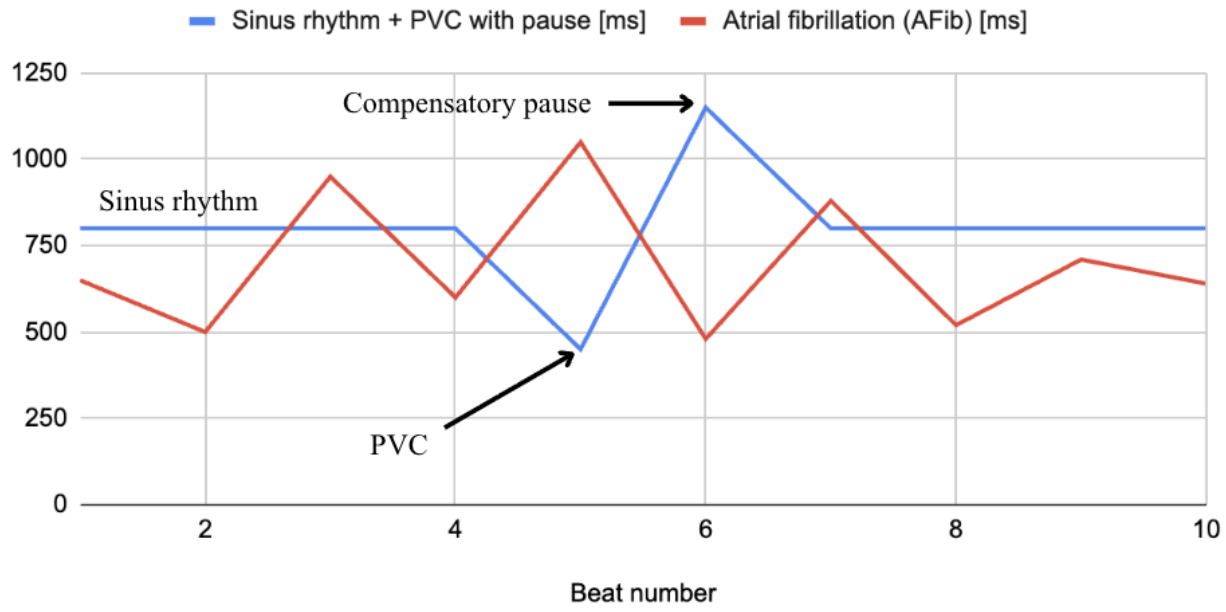

Fig. 3. *A side-by-side comparison of photoplethysmography (PPG) tachograms showing a premature ventricular contraction (PVC) next to an actual episode of atrial fibrillation (AF). Current consumer smartwatches frequently struggle to differentiate between completely benign ectopic beats and severe atrial fibrillation (AF). When a premature contraction occurs, the resulting irregularity in pulse timing is often misinterpreted by the device's rigid algorithms as the chaotic pattern of AF.*

Because flagship models lack the specific software required to identify these harmless ectopic beats automatically, users are frequently bombarded with false-positive arrhythmia alerts or vague "Inconclusive" notifications. From a socio-technical perspective, this algorithmic blind spot is highly problematic, as it directly generates significant, technology-induced health anxiety for the consumer.

However, this technological limitation also underscores a critical boundary in digital healthcare. While the artificial intelligence may fail to contextualize crude pulse disruptions, a trained physician can easily identify the benign nature of the rhythm by reviewing the raw ECG data exported by the patient. Ultimately, this dynamic highlights the smartwatch's true utility as a highly accessible digital symptom recorder rather than an autonomous diagnostic tool. It strongly reinforces the ethical and medical imperative that final diagnostic authority must remain with a human professional, preventing the blind outsourcing of clinical decisions to artificial intelligence (Duncker et al., 2021).

5.2. Severe Tachyarrhythmias: The Limits of Human-Device Interaction

While smartwatch algorithms are highly optimized for atrial fibrillation, they inevitably capture other severe tachyarrhythmias (abnormally fast heart rates). However, rigid commercial software frequently misinterprets these rapid, regular rhythms, defaulting to vague "Inconclusive" or "High Heart Rate" alerts rather than providing a specific diagnosis.

Despite this algorithmic limitation, the ability of patients to instantly export raw ECG data during symptomatic episodes bridges a crucial gap between consumer tracking and professional clinical intervention (Duncker et al., 2021).

However, a more profound socio-technical limitation emerges with life-threatening ventricular arrhythmias. Although the device's hardware is theoretically capable of recording these events, the diagnostic process relies entirely on active user engagement. To successfully capture an ECG, the patient must remain conscious, calm, and hemodynamically stable enough to hold their finger on the device's crown for 30 seconds.

In real-world scenarios of severe arrhythmias that cause rapid syncope (fainting), this human-computer interaction fundamentally fails. Because of this undeniable practical flaw, official guidelines, including those from the European Heart Rhythm Association (EHRA), explicitly warn against relying on consumer wearables as substitutes for professional clinical telemetry in high-risk populations, clearly delineating the boundary between commercial health gadgets and life-saving medical equipment (Svennberg et al., 2022).

5.3. Bradycardia and Conduction Blocks: The Clinical Utility of Low Heart Rate Notifications

While rapid arrhythmias often dominate the clinical discourse surrounding wearable technology, consumer smartwatches also serve a vital role in detecting bradyarrhythmias (abnormally slow heart rates). Relying on passive photoplethysmography (PPG) sensors cross-referenced with built-in accelerometers, these devices can accurately differentiate between naturally low resting heart rates and potentially dangerous drops in pulse. Users can establish personalized low-heart-rate thresholds, allowing the software to automatically generate an alert if the pulse falls below a critical level for an extended period.

From a socio-technical perspective, this continuous background surveillance is highly impactful. It empowers individuals experiencing vague, insidious symptoms such as unexplained fatigue or dizziness to document early signs of conditions like Sick Sinus Syndrome long before a severe syncopal episode occurs (Duncker et al., 2021).

Although single-lead smartwatch ECGs face technical limitations in visualizing the subtle electrical waves necessary to differentiate complex conduction blocks, their primary value lies in preliminary screening rather than definitive diagnosis. Simply recording a sustained bradycardic baseline or a significant cardiac pause provides undeniable, actionable data. This effectively shifts the initiation of specialized cardiological care directly into the hands of the patient, prompting timely medical referrals based on real-world, consumer-generated evidence (Duncker et al., 2021; Svennberg et al., 2022).

Table 2. Summary of the diagnostic characteristics for detecting non-atrial fibrillation (non-AF) cardiac arrhythmias utilizing consumer smartwatch algorithms. *Source: Authors' original synthesis, adapted from Duncker & Veltmann (2021) and Svennberg et al. (2022).*

Arrhythmia Type (Clinical Diagnosis)	Typical User Notification	Visible mECG Characteristics (For the Physician)	Main Algorithmic Challenge
Premature contractions (PVCs / PACs)	"Inconclusive" or "Suspected Atrial Fibrillation" (False positive)	Narrow (PAC) or wide (PVC) QRS complexes; visible compensatory pause	The compensatory pause mimics the irregularity typical of atrial fibrillation (chaos)
Supraventricular tachycardia (SVT)	"High Heart Rate" (>120 bpm) or "Inconclusive"	Regular rhythm, rapid heart rate, narrow QRS complexes. Absence of visible P waves	The rhythm is too regular to be classified as AFib, but too fast for a normal sinus rhythm
Ventricular tachycardia (VT)	"High Heart Rate" or no notification (syncope)	Wide, bizarre QRS complexes; very rapid heart rate	Life-threatening condition – the patient may lose consciousness before activating the ECG app
Bradycardia / AV block	"Low Heart Rate" (<40–50 bpm)	Slow rhythm; possible dropped QRS complexes (pauses) or P-QRS dissociation	The low amplitude of P waves on a smartwatch makes it difficult to differentiate the type of block

6. Technical and Clinical Limitations

Even with the incredible advancements in artificial intelligence and detection software, bringing commercial smartwatches into everyday clinical practice faces significant hurdles, challenges that are deeply tied to the actual physics of optical sensors and the natural physical differences between individual patients.

The most fundamental flaw of photoplethysmography (PPG) hardware is its extreme sensitivity to outside interference. Out in the real world, everyday arm movements and changing environmental conditions severely corrupt the quality of the recording - a stark contrast to the perfectly controlled, quiet setting of a hospital ward.

Beyond the physical limitations of the hardware itself, the massive, worldwide popularity of these consumer gadgets creates an entirely new set of headaches for the modern medical system. Chief among these are the growing epidemic of overdiagnosis and the very real danger of anxious patients completely misinterpreting their own raw health data. The following section dives into these crucial constraints - the exact factors that ultimately define the current margin of error for wearable cardiac monitors (Svennberg et al., 2022).

6.1. Motion Artifacts, Cyberchondria, and the Associated Burden on Healthcare Systems

The biggest technical hurdle in continuous, everyday heart monitoring is simply how sensitive optical PPG sensors are to physical motion. Unlike a traditional ECG taken while the patient lies perfectly still on an examination table, consumer smartwatches are worn all day long through activities ranging from intense jogging to simple typing or animated hand gestures. These ordinary movements cause the watch to shift microscopically against the skin and temporarily alter the local blood pressure in the wrist's veins. This physical friction creates a massive amount of mechanical interference or noise that often completely drowns out the patient's actual pulse. In the medical tech world, this disruption is universally known as a motion artifact, and it severely ruins the Signal-to-Noise Ratio (SNR) of the recording (Svennberg et al., 2022).

When looking at this from a software standpoint, the chaotic optical waves caused by a shifting sensor look incredibly similar to the erratic pulse of atrial fibrillation. This digital confusion directly triggers a massive wave of false-positive notifications. Clinical data clearly shows that during heavy exercise, the software's error rate skyrockets making these optical sensors virtually useless for diagnosing true arrhythmias while the user is actively working out (Svennberg et al., 2022).

Moving past the physical hardware, the explosion of 24/7 biometric tracking has sparked a completely new set of psychological side effects. Often described in modern medical literature as "cyberchondria" or tech-induced health anxiety - this issue drives people to obsessively check their pulse, frequently mistaking totally normal heart rate changes for a deadly cardiac disease (Dörr et al., 2019; Piwek et al., 2016). It is incredibly easy for smartwatch owners to get trapped in a vicious "anxiety feedback loop." For example, getting a vague warning on their wrist like an "Inconclusive" or "High Heart Rate" alert immediately triggers an acute psychological stress response.

This sudden panic causes a very real physiological reaction, pushing the heart into sinus tachycardia. The watch then picks up on this newly elevated pulse and flags it as yet another abnormality throwing the user into an even deeper state of panic. Psychological studies highlight that for certain patients, the wearable device morphs from a helpful preventative tool into a relentless source of daily dread (Piwek et al., 2016). This phenomenon is deeply rooted in the concept of 'technostress' - a well-documented psychological condition where the continuous use of information and communication technologies inadvertently generates mental fatigue and anxiety (Salanova et al., 2013). In the context of consumer wearables, this 'dark side of technology' manifests as cyberchondria, where the constant stream of raw biometric data and automated alerts overloads the user, transforming healthy individuals into hyper-vigilant patients.

As a direct consequence of this tech boom, hospitals and clinics are facing a totally new logistical nightmare - a massive influx of the "worried well." These are generally healthy, completely asymptomatic people with zero cardiovascular risk factors who rush to the clinic because their watch sent them a bad alert - an alert usually triggered by nothing more than a motion artifact. The harsh reality is that every single one of these digital warnings requires a formal medical workup to safely rule out true pathology, a process that almost always involves a physical exam and a standard 12-lead ECG. This defensive medicine eats up countless clinical hours and places an enormous, unjustified financial burden on the broader healthcare system.

Because of this, experts at the European Heart Rhythm Association (EHRA) are waving a massive red flag about two connected dangers: rampant systemic overdiagnosis and severe "alarm fatigue" among doctors. Instead of spending their shifts treating high-risk cardiac patients who desperately need medical intervention, cardiologists are finding themselves forced to manually sift through thousands of completely harmless, consumer-generated rhythm strips (Duncker et al., 2021; Svennberg et al., 2022).

6.2. Demographic Diversity: The Impact of Skin Pigmentation and Age on PPG Signal Quality

The clinical reliability of consumer wearables is surprisingly inconsistent across different patient populations. Recent validation data clearly shows a strong link between how well an algorithm performs and a user's physical characteristics, most notably their skin color and age. This technological gap raises serious questions about digital health equity, strongly suggesting that today's commercial software is fundamentally less accurate for certain demographic groups.

The core engineering behind almost all popular smartwatches including flagship models from Apple, Fitbit, and Garmin, depends on photoplethysmography (PPG) powered by green light-emitting diodes, which operate at a wavelength of roughly 530 nm. Manufacturers specifically choose the green light spectrum because it is highly absorbed by hemoglobin, making it much easier to detect the wearer's pulse. The major flaw in this design, however, is that epidermal melanin also heavily absorbs this exact same wavelength.

For patients with darker skin tones specifically those classified as Fitzpatrick skin types V and VI this high concentration of melanin acts like a thick optical wall. It essentially blocks a massive amount of the emitted light photons before they even have a chance to reach the blood vessels underneath the skin. Ultimately, this physical barrier drastically drops the device's Signal-to-Noise Ratio (SNR).

A landmark study published in *NPJ Digital Medicine* by Bent et al. (2020) perfectly illustrated this issue, proving that standard wearables have a much higher rate of measurement errors in patients with darker complexions - a technical failure that gets significantly worse when the user is actively exercising. In this specific group, the device's software frequently fell victim to what are known as "crossover errors." Essentially, the algorithm completely lost the actual cardiac pulse and mistakenly locked onto the patient's step rate, or running cadence, instead. This kind of software confusion is incredibly risky, as it can easily trigger unnecessary false alarms or entirely miss a genuine episode of tachycardia.

Aside from skin pigmentation, advanced age is another major demographic factor that severely ruins signal quality. The natural aging process triggers several structural changes in the microvascular system including a noticeable drop in dermal capillary density and a steady increase in arterial stiffness. Because of these physiological shifts, older patients naturally suffer from poorer peripheral blood flow, particularly in the extremities like the wrist.

As a result, the optical PPG waveform picked up by the watch looks visibly "blunted" or flattened out, making it extremely hard for the software to separate the true pulse from random background noise. As the European Heart Rhythm Association (EHRA) guidelines clearly point out, elderly patients run the highest risk of getting frustrating "Inconclusive" readings from their devices. This leads to a massive clinical paradox - the exact population that is at the highest risk for developing atrial fibrillation, and therefore needs this screening the most, is the very same group most restricted by the hardware's physical limitations (Svennberg et al., 2022).

7. Clinical Implementation and Legal Considerations

The rapid explosion of wearable technology is forcing the medical community to completely rethink the line between a standard consumer gadget and a true clinical tool. Just slapping a biometric sensor onto a smartwatch does not automatically make it a valid piece of diagnostic medical equipment. To actually earn a legitimate spot in a formal clinical workflow, this technology has to pass incredibly strict safety and performance tests. Globally, regulatory bodies now classify these sophisticated algorithms under a very specific, highly regulated framework officially known as Software as a Medical Device (SaMD).

As a direct result, bringing millions of these smartwatches into everyday clinical practice creates a massive wave of new legal and ethical headaches for doctors. The biggest issue revolves around Patient-Generated Health Data (PGHD) specifically, how physicians can actually trust and verify this incoming, unprompted information.

Doctors are currently struggling with the logistics of importing this constant stream of outside telemetry into official electronic health records (EHRs). They need a way to do this safely without opening themselves up to devastating malpractice lawsuits if the artificial intelligence makes a mistake, or if the physician personally misses a hidden diagnosis buried in the raw data.

The next section breaks down exactly how government agencies in both the United States and the European Union are currently regulating these arrhythmia-detecting algorithms. Furthermore, it brings together the latest clinical guidelines and official consensus statements from major cardiovascular societies - detailing exactly how these digital tools should be deployed responsibly in modern patient care (Svennberg et al., 2022).

7.1. Medical Certification (FDA and CE Marking): Distinguishing Legitimate Diagnostic Wearables from Recreational Gadgets

The ultimate dividing line between a simple fitness gadget and a trustworthy clinical tool comes down to one thing - formal regulatory approval. Specifically, this means securing clearance from the US Food and Drug Administration (FDA) or obtaining the Conformité Européenne (CE) mark across Europe.

Under current medical law, the actual physical smartwatch is rarely classified as the medical device itself. Instead, the hardware simply acts as a vehicle for what is known as Software as a Medical Device (SaMD). It is actually the underlying digital algorithm - the code responsible for analyzing the ECG or PPG signals that faces intense clinical vetting, rather than the metal casing on the user's wrist.

Looking at the FDA's regulatory framework, the ECG applications built into popular smartwatches including major models from Apple, Samsung, Fitbit, and Withings fall under the category of Class II medical devices. This specific label implies a moderate level of risk, meaning that before these companies can sell their software, they are legally required to prove "substantial equivalence." Essentially, they must conduct extensive clinical trials showing that their app performs just as well as the established gold standard - the traditional hospital ECG (Svennberg et al., 2022).

A massive turning point in digital health happened back in 2018, when the FDA granted a De Novo classification to the Apple Watch Series 4. To win this groundbreaking approval, Apple had to hand over a mountain of clinical data largely gathered during the famous Apple Heart Study, demonstrating that their software could successfully tell the difference between a normal sinus rhythm and atrial fibrillation. The algorithm had to hit very strict performance targets, achieving both sensitivity and specificity scores well above the 90% mark. Only after passing these grueling regulatory hurdles can a tech company legally advertise their software as a genuine medical tool for detecting arrhythmias (Isakadze & Martin, 2020; Svennberg et al., 2022).

Because of these strict rules, a hard medicolegal line now separates true clinical wearables from basic "wellness" trackers. Medical-grade smartwatches carry official FDA or CE certifications for highly specific functions like "Atrial Fibrillation Detection" which means doctors can safely use their data to guide further diagnostic testing. The most well-known devices in this top tier include the Apple Watch, the Samsung Galaxy Watch (from the Active 2 model onward), the Fitbit Sense, and the Withings ScanWatch.

On the flip side of the market are recreational wellness trackers, usually cheap fitness bands that track a basic pulse but are legally forced to include a "Not for medical use" warning in their manuals. These casual gadgets skip the clinical trial process entirely, meaning their internal algorithms never undergo formal quality control. From a doctor's perspective, the data coming from these unregulated, off-brand smartbands is fundamentally untrustworthy and should absolutely never be used to make real therapeutic decisions (Svennberg et al., 2022).

Therefore, it is absolutely critical for practicing physicians to double-check whether a patient's specific smartwatch actually holds a valid CE mark - one that strictly complies with the latest European Medical Device Regulation (MDR) regarding its ECG functions. Confirming this certification is the only way a doctor can be sure that the software has survived a brutal clinical testing pipeline, proving it is a reliable diagnostic aid rather than just a digital toy generating random squiggly lines (Svennberg et al., 2022).

7.2. Telemedicine Integration: Clinical Management of Smartwatch-Acquired Electrocardiograms

As consumer smartwatches become wildly popular, doctors are increasingly coming face-to-face with a massive new wave of Patient-Generated Health Data (PGHD). The traditional way of diagnosing arrhythmias which used to rely entirely on doctors ordering bulky Holter monitors is quickly morphing into a shared, hybrid approach. In today's clinical landscape, patients are actually taking the initiative to record and email their own hard electrical evidence of heart rhythm problems, usually sending these over as standard, single-lead ECG PDFs.

A massive turning point for the medical acceptance of this everyday technology came when the 2020 European Society of Cardiology (ESC) guidelines for atrial fibrillation were officially published. This core medical text still strictly requires clear ECG proof to formally diagnose AF. However, the game-changer is that these guidelines officially broadened what counts as acceptable evidence, ruling that a simple single-lead ECG strip lasting at least 30 seconds is completely valid for diagnosis, as long as a trained physician personally reviews and confirms the tracing (Hindricks et al., 2021; Svennberg et al., 2022).

This update represents an absolutely massive shift in both clinical practice and medical law. Right now, a clean, high-quality ECG recorded on an approved wearable like an Apple Watch or a Samsung Galaxy Watch

can legally act as the sole foundation for diagnosing atrial fibrillation and safely starting a patient on life-saving blood thinners. As long as the digital tracing is clear and shows the classic signs of the arrhythmia - specifically, missing P waves combined with an irregularly irregular ventricular rhythm doctors no longer have to wait weeks to schedule a traditional Holter monitor. This is an incredible advantage when trying to catch sneaky, paroxysmal AF episodes that a standard 24-hour hospital monitor almost always misses.

Following the practical roadmap laid out by the European Heart Rhythm Association (EHRA) back in 2022, any doctor who receives a smartwatch ECG from a patient needs to run through a very specific, three-step clinical checklist:

- **Technical Appraisal:** First, the physician must check the overall quality of the recording - making sure the QRS complexes are sharp and ruling out any heavy interference from muscle tremors or movement.
- **Clinical Adjudication:** Next, the doctor has to critically judge the watch's automated guess. The human clinician must always independently confirm the rhythm - constantly remembering that the AI is notorious for mixing up harmless ectopic beats with true atrial fibrillation.
- **Formal Documentation:** Finally, the actual PDF file showing the abnormal rhythm must be permanently uploaded into the patient's Electronic Health Record (EHR). This step is absolutely mandatory, as it serves as the ultimate legal proof justifying any future medical treatments (Svennberg et al., 2022).

Even with all these obvious diagnostic perks, the biggest danger of wearable-based telemedicine is the very real threat of drowning doctors in data. Overly anxious or enthusiastic patients might start emailing dozens of perfectly normal ECG strips every single week, fully expecting their doctor to reply immediately.

Because of this, setting hard boundaries for communication is absolutely vital. Doctors must clearly instruct their patients to only send in their PDFs when they are actually feeling acute symptoms or when the watch triggers a specific red alert - not just to share their daily baseline rhythm. If hospitals do not set up smart digital triage systems to manage this massive flood of biometric data, they risk completely burning out their medical staff, which ironically could end up hurting overall patient care rather than helping it (Svennberg et al., 2022).

7.3. Recommendations from Leading Cardiovascular Societies (ESC and AHA)

The massive surge in patients wearing smart devices every day has practically forced the world's leading cardiovascular organizations to completely rewrite their standard clinical playbooks. Looking at the latest guidelines published by the European Society of Cardiology (ESC) - alongside the formal scientific statements released by the American Heart Association (AHA), it is clear that the medical community has finally moved away from its initial skepticism. Today, these major societies have adopted a stance of cautious approval, though this acceptance heavily depends on strict, hands-on supervision by a real doctor.

A massive breakthrough for the entire field of digital medicine arrived when the ESC released its updated 2020 guidelines specifically targeting the diagnosis and daily management of atrial fibrillation. This landmark publication completely changed the official rules regarding how clinical diagnoses are formally established.

Based on a highly authoritative Class I recommendation (Level of Evidence B), officially confirming a diagnosis of atrial fibrillation now merely requires a clear electrical tracing from a single lead lasting for at least 30 uninterrupted seconds, just as long as a trained medical professional personally reviews the strip and verifies the abnormal rhythm.

Translating this into everyday medical practice, this update means that a simple PDF file exported directly from an approved consumer wearable like an Apple Watch or a Withings ScanWatch now carries the exact same clinical weight as a traditional hospital ECG when a physician is making critical decisions about starting a patient on life-saving anticoagulant therapy. This newly accepted diagnostic pathway - detailing the journey from a smartwatch alert to formal medical treatment, is clearly mapped out in Figure 4 (Hindricks et al., 2021).

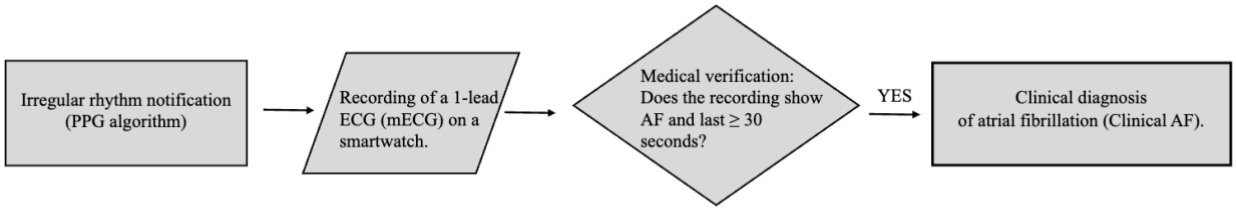

Fig. 4. *An updated diagnostic algorithm for atrial fibrillation (AF) incorporating wearable technology, adapted from the 2020 European Society of Cardiology (ESC) guidelines. Under this revised clinical paradigm, a smartwatch-derived, single-lead ECG tracing of at least 30 seconds in duration - once independently verified by a physician is deemed sufficient to establish a definitive clinical diagnosis (Class I recommendation, Level of Evidence B). Source: Authors' original synthesis based on Hindricks et al. (2021).*

It is absolutely essential to highlight a major clinical distinction clearly drawn by the ESC. The optical photoplethysmography (PPG) sensor is designed exclusively for early-stage screening. A simple "irregular rhythm" alert popping up on a smartwatch is never a formal clinical diagnosis, instead, it acts strictly as a medical "red flag" that demands further professional investigation.

On the flip side, the watch's active electrical feature - the single-lead ECG, can actually be used to lock in a definitive diagnosis, just as long as the generated electrical tracing is clear enough for a doctor to confidently interpret (Hindricks et al., 2021; Svennberg et al., 2022).

Interestingly, both European and American cardiology experts, including the ESC and the AHA/ACC, remain highly cautious about rolling out massive, systematic screening programs for the general public. Their biggest collective worry revolves around the very real danger of overdiagnosis. Treating low-risk, otherwise healthy individuals could easily lead to unnecessary overtreatment, creating a dangerous scenario where the preventative benefits of blood thinners simply do not outweigh the serious risks of major internal bleeding.

Because of these clinical risks, the current medical consensus strongly supports a strategy known as opportunistic screening (Svennberg et al., 2022). Essentially, this means that doctors should not go out of their way to prescribe or recommend the purchase of smartwatches to perfectly healthy, asymptomatic patients. However, if a patient already happens to own and wear one of these devices, the physician should absolutely take advantage of that continuous biometric data. In this specific scenario, the smartwatch becomes a fantastic, supplementary diagnostic tool during a routine patient interview (Svennberg et al., 2022).

Ultimately, the world's top cardiology organizations have officially embraced consumer smartwatches as highly valuable auxiliary tools in modern clinical practice. This massive shift in medical thinking effectively moves the primary burden of responsibility. The defining clinical question is no longer "does this commercial gadget actually work?" but rather, "is the attending physician fully capable of properly interpreting the data it provides?"

8. Discussion

A rigorous economic breakdown of the digital health sector reveals that massive, corporate-backed research projects, specifically the Apple Heart Study (AHS), Huawei Heart Study (HHS), and the Fitbit Heart Study brilliantly accomplished two things at once. They pushed scientific boundaries while simultaneously acting as spectacular, global marketing campaigns. When mainstream media heavily broadcasted the results of these clinical trials, the tech giants behind them experienced an absolute explosion in hardware sales. Naturally, this undeniable link sparks deep ethical concerns regarding how medical credibility is being actively commercialized.

Apple’s financial journey is the perfect illustration of this trend. The highly publicized 2019 release of the AHS data, combined with securing that historic FDA De Novo clearance, completely transformed the company's product strategy. Market statistics show that shipments of the Apple Watch skyrocketed from roughly 22 million units in 2018 to well over 30 million by 2019. This explosive growth only accelerated in the following years, ultimately blowing past the 50 million mark by 2022 (Curry, 2024). By purposely "medicalizing" a standard consumer gadget, Apple successfully captured an entirely new, highly lucrative audience - older, health-conscious buyers who had previously written off smartwatches as useless digital toys.

Rival tech companies quickly caught on and mirrored this highly profitable playbook. By aggressively marketing its enormous, collaborative study with the Chinese PLA General Hospital - a project involving an astonishing cohort of more than 5 million individuals, Huawei successfully rebranded itself as a pioneer in cardiovascular care, effectively locking down its absolute market dominance in China (Guo et al., 2020). Similarly, after publishing its own robust clinical data and scoring regulatory approval for its PPG software in 2020, Fitbit successfully stopped its user base from jumping ship. The brand managed to convince everyday buyers that its more affordable, budget-friendly fitness bands offered the exact same "medical-grade precision" as the far more expensive flagship models (Svennberg et al., 2022).

Despite these corporate victories, leading voices within the bioethics and medical communities are raising serious red flags, warning that this model of industry-funded science subtly manipulates public health priorities. These blockbuster trials tend to loudly celebrate their relative clinical victories such as proudly finding asymptomatic arrhythmias in just 0.5% of a gigantic test group.

However, they conveniently ignore a glaring epidemiological truth: for the average, totally healthy user with a low cardiovascular risk profile, dropping hundreds of dollars on a cardiac surveillance tool makes absolutely zero sense from a public health or pharmacoeconomic perspective (Curry, 2024; Guo et al., 2020). At its core, this dynamic threatens to twist legitimate scientific validation into a highly sophisticated sales tactic - leveraging the coveted "FDA stamp of approval" to trick perfectly healthy people into buying a technological cure for a disease they do not even have.

Beyond the financial implications, the constant pressure to track every single biometric data point carries heavy psychological baggage. A close look at the current scientific literature reveals a dark, anxiety-inducing side to wearing these devices 24/7. As Piwek et al. (2016) pointed out in *PLoS Medicine*, the initial excitement surrounding the "Quantified Self" trend very frequently devolves into severe health anxiety.

Instead of feeling safe, users routinely fall into an obsessive cycle of checking their vitals, which ultimately turns normal, everyday life into a constant medical test. Because of this hyper-awareness, perfectly natural, temporary physical reactions like a bout of stress-induced sinus tachycardia are immediately catastrophized by the user as hard proof of a deadly heart condition. As a result, a gadget that was originally sold to improve holistic health ironically acts as a massive trigger for chronic stress and a false sense of physical fragility - a toxic cycle that frequently drives users to abandon the device altogether (Piwek et al., 2016).

Inevitably, this tech-fueled anxiety bleeds right into the clinic, deeply disrupting the traditional doctor-patient dynamic. Patients regularly walk away feeling dismissed and angry when their doctors refuse to panic over a messy smartwatch tracing, viewing the expensive gadget as an unreliable toy. On the flip side, physicians are feeling completely burnt out by the sheer volume of patients demanding instant, free interpretations of their digital data - a time-consuming service that hospitals simply do not bill or pay for. This growing friction threatens to completely destroy the therapeutic alliance, which is the absolute bedrock of good clinical medicine (Vayena et al., 2015).

Finally, a massive ethical storm is brewing over the critical issue of data privacy. In a deeply detailed review, Cilliers (2020) highlights a growing wave of patient anxiety regarding the secret commercialization of their most intimate health metrics. There is a highly justified, terrifying fear that extremely sensitive cardiovascular data - currently sitting on the massive cloud servers of Big Tech companies, could easily be weaponized for non-medical profit. The ultimate nightmare scenario involves health insurance companies buying this actuarial risk data to silently practice price discrimination - automatically hiking up premium rates the moment an algorithm detects an asymptomatic arrhythmia. Ultimately, the chilling feeling of living under constant digital surveillance is repeatedly flagged as one of the most impenetrable ethical roadblocks preventing these smart devices from being universally adopted in clinical medicine (Cilliers, 2020).

9. Conclusions

The comprehensive literature review conducted herein unequivocally indicates that the commercial introduction of smartwatches equipped with electrocardiogram (ECG) and photoplethysmography (PPG) modules represents a definitive turning point in preventative cardiology. This technological leap has catalyzed a paradigm shift, transitioning the field from a historically reactive diagnostic model toward a system of continuous, proactive health monitoring.

Under meticulously controlled conditions, contemporary detection algorithms have achieved a degree of diagnostic precision that closely rivals the traditional medical "gold standard." This milestone is explicitly reflected in the updated 2020 European Society of Cardiology (ESC) guidelines, which formally sanction these consumer wearables as reliable preliminary screening instruments for atrial fibrillation.

Nevertheless, it is imperative to emphasize that high technical efficacy does not invariably translate into real-world clinical effectiveness. However, high technical efficacy does not seamlessly translate into real-world equity. The fundamental reliability of these biometric sensors is heavily constrained by biological variables, particularly epidermal pigmentation and age-related vascular changes. Consequently, this technology creates a tangible risk of digital health exclusion, systematically leaving elderly populations and individuals with darker skin tones at a diagnostic disadvantage.

Furthermore, the mass consumer adoption of wearable technology introduces profound psychosocial ramifications. The ongoing medicalization of everyday life and the escalating prevalence of "cyberchondria" when coupled with aggressive corporate marketing strategies threaten to severely overwhelm existing healthcare infrastructures with an influx of the "worried well," thereby diverting resources from patients who genuinely require urgent intervention.

Ultimately, despite the explosive advancement of artificial intelligence, the smartwatch remains, at its core, merely a sophisticated clinical event recorder rather than an autonomous diagnostician. The cornerstone for safely integrating this technology into modern medicine lies in preserving the paramount, non-negotiable role of independent physician verification. Moving forward, the scientific community must prioritize the execution of independent, conflict-free clinical trials. Only through unbiased, long-term observation can we objectively evaluate whether continuous wearable monitoring actually translates into a meaningful reduction in stroke incidence across the general population.

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Abbreviations

The following abbreviations are used in this manuscript:

ACC – American College of Cardiology
AF – Atrial Fibrillation
AHA – American Heart Association
AHS – Apple Heart Study
AI – Artificial Intelligence
AV – Atrioventricular
BPM – Beats Per Minute
CE – Conformité Européenne
CNN – Convolutional Neural Networks
DL – Deep Learning
ECG / EKG – Electrocardiogram
EHR – Electronic Health Record
EHRA – European Heart Rhythm Association
ESC – European Society of Cardiology
FDA – Food and Drug Administration
FHS – Fitbit Heart Study
HHS – Huawei Heart Study
LED – Light Emitting Diode
MAFA – Mobile Atrial Fibrillation App
mECG – Mobile Electrocardiogram
MDR – Medical Device Regulation
mHealth – Mobile Health
ML – Machine Learning
OAC – Oral Anticoagulation
PAC – Premature Atrial Contraction
PGHD – Patient-Generated Health Data
PPG – Photoplethysmography
PPV – Positive Predictive Value
PVC – Premature Ventricular Contraction

SaMD – Software as a Medical Device
SNR – Signal-to-Noise Ratio
SQI – Signal Quality Index
SSS – Sick Sinus Syndrome
SVT – Supraventricular Tachycardia
VT – Ventricular Tachycardia

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