



# International Journal of Innovative Technologies in Social Science

e-ISSN: 2544-9435

**Operating Publisher**  
**SciFormat Publishing Inc.**  
ISNI: 0000 0005 1449 8214

2734 17 Avenue SW,  
Calgary, Alberta, T3E0A7,  
Canada  
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## ARTICLE TITLE

AUTOMATED DETECTION OF OUT-OF-HOSPITAL CARDIAC  
ARREST USING WEARABLE TECHNOLOGY: A SYSTEMATIC  
SCOPING REVIEW OF DIAGNOSTIC ACCURACY, REAL-WORLD  
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## DOI

[https://doi.org/10.31435/ijitss.2\(50\).2026.5561](https://doi.org/10.31435/ijitss.2(50).2026.5561)

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## RECEIVED

11 March 2026

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## ACCEPTED

27 June 2026

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## PUBLISHED

30 June 2026

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# **AUTOMATED DETECTION OF OUT-OF-HOSPITAL CARDIAC ARREST USING WEARABLE TECHNOLOGY: A SYSTEMATIC SCOPING REVIEW OF DIAGNOSTIC ACCURACY, REAL-WORLD FEASIBILITY, AND ETHICAL IMPLICATIONS**

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**ABSTRACT**

Out-of-hospital cardiac arrest (OHCA) is characterized by an exceptionally low survival rate, primarily due to delayed recognition in unwitnessed cases (Gräsner et al., 2021; Hutton et al., 2022). This scoping review aims to evaluate the diagnostic accuracy, real-world feasibility, and ethical implications of using commercial smartwatches for the automated detection of OHCA (Hutton et al., 2022; Eversdijk et al., 2024). Electronic databases (including PubMed and PMC) were searched for publications spanning 2019–2026, identifying high-quality studies in accordance with the PRISMA-ScR guidelines. The analysis focused on multimodal algorithms combining photoplethysmography (PPG) with triaxial accelerometry (Schober et al., 2022; Shah et al., 2025).

Results indicate that these algorithms achieve a sensitivity of approximately 98% and a specificity of 99% in simulation studies (Schober et al., 2022). The first documented case reports confirm successful automated detections in real-world settings, demonstrating the potential to significantly reduce emergency medical services (EMS) response times (Edgar et al., 2026; Scquizzato et al., 2020; Eversdijk et al., 2024). Major identified barriers include motion artifacts, health disparities resulting from degraded PPG performance in individuals with darker skin tones, and the risk of alert fatigue caused by false-positive calls (Bent et al., 2020; Eversdijk et al., 2024; van der Eerden et al., 2025). Ethical integration necessitates the implementation of "dynamic consent" models to safeguard patient privacy (Kaye et al., 2015; Eversdijk et al., 2024).

In conclusion, wearable devices represent a breakthrough tool capable of acting as "digital witnesses" to significantly strengthen the chain of survival (Schober et al., 2022; Semeraro et al., 2021). However, their widespread implementation requires AI-driven optimization, the mitigation of algorithmic biases, and rigorous integration with emergency dispatch systems (Scquizzato et al., 2020; Shah et al., 2025).

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**KEYWORDS**

Out-of-Hospital Cardiac Arrest, Wearable Technology, Smartwatch, Photoplethysmography, Automated Detection, Chain of Survival

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**CITATION**

Zofia Sinczak, Aleksandra Zofia Sobol, Stanisław Bajerski, Anna Maria Kowalska, Sonia Zembrzuska, Justyna Maria Wiktorowicz, Martyna Kadłubańska, Aleksandra Anna Kuls, Bogusław Pabis, Nicole Bulińska. (2026) Automated Detection of Out-of-Hospital Cardiac Arrest Using Wearable Technology: a Systematic Scoping Review of Diagnostic Accuracy, Real-World Feasibility, and Ethical Implications. *International Journal of Innovative Technologies in Social Science*. 2(50). doi: 10.31435/ijitss.2(50).2026.5561

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**Introduction**

Out-of-hospital cardiac arrest (OHCA) remains one of the most critical, devastating, and time-sensitive global public health emergencies, accounting for a substantial proportion of all cardiovascular-related mortalities worldwide (Gräsner et al., 2021; Hutton et al., 2022). OHCA is characterized by an abrupt and catastrophic cessation of mechanical cardiac activity, leading to immediate hemodynamic collapse and an acute halt in systemic perfusion. Despite decades of robust clinical research, progressive advancements in emergency medical services (EMS), widespread public cardiopulmonary resuscitation (CPR) education, and the extensive societal deployment of automated external defibrillators (AEDs), survival rates to hospital discharge have plateaued globally, typically hovering around an alarmingly low 8–10% (Gräsner et al., 2021). Furthermore, among those who do survive, a significant percentage suffer from profound, irreversible hypoxic-ischemic encephalopathy, severely compromising their long-term quality of life and placing a massive burden on healthcare infrastructures.

A fundamental determinant of OHCA survival is the "chain of survival" concept, a sequential, time-critical paradigm encompassing the early recognition of cardiac arrest and rapid activation of the emergency response system, the immediate initiation of high-quality bystander CPR, rapid defibrillation, advanced life support interventions by professional EMS teams, and comprehensive post-cardiac arrest care (Semeraro et al., 2021). The integrity and efficacy of this entire chain, however, depend absolutely on its foundational first link: the immediate recognition that a cardiac arrest has occurred. When an event is witnessed by a bystander,

prompt distress calls to 112/911 and life-saving interventions are practically feasible. Yet, a major epidemiological and systemic challenge is that approximately 50–70% of OHCA cases are unwitnessed, occurring mostly in private residences, during solitary physical activities, or during sleep (Gräsner et al., 2021).

In unwitnessed scenarios, the critical concept of "no-flow time"—the duration between the onset of asystole or ventricular fibrillation and the commencement of artificial perfusion via CPR—becomes the primary arbiter of mortality. Cellular adenosine triphosphate (ATP) stores in the brain are depleted within minutes of perfusion loss. Consequently, the delay between the onset of the event and the arrival of professional help in unwitnessed cases typically exceeds the critical 10-minute threshold, after which the risk of irreversible neurological damage or death approaches 100% (Hutton et al., 2022). Therefore, identifying unwitnessed OHCA immediately at the time of collapse represents the single most significant frontier in resuscitation science.

The rapid evolution of wearable technology, particularly commercially available smartwatches and fitness trackers, has created an unprecedented and transformative opportunity to bridge this fatal gap in the chain of survival. Over the past decade, these ubiquitous consumer devices have transitioned from rudimentary pedometers into highly sophisticated, medical-grade diagnostic tools capable of continuous, non-invasive physiological monitoring. The hardware foundation of this transition lies in the miniaturization and integration of photoplethysmography (PPG) sensors, which allow for the continuous optical assessment of pulsatile blood volume changes in the microcirculation of the wrist, alongside micro-electromechanical systems (MEMS) such as triaxial accelerometers and gyroscopes (Schober et al., 2022).

The clinical efficacy of these wearable devices in detecting specific cardiovascular abnormalities, particularly arrhythmias such as atrial fibrillation (AFib), has already been vigorously validated in massive, landmark clinical trials. Notably, the Apple Heart Study, which enrolled over 400,000 participants, unequivocally demonstrated that consumer smartwatches could accurately identify irregular pulse patterns, leading to widespread regulatory approvals from bodies like the FDA and the EMA (Perez et al., 2019). However, detecting a sudden cardiac arrest poses a significantly more complex physiological and algorithmic challenge than arrhythmia detection. While AFib detection relies on identifying rhythm irregularity in an otherwise actively perfusing patient, OHCA detection requires the accurate identification of a sudden, complete, and sustained cessation of pulsatile blood flow, frequently accompanied by a simultaneous loss of postural tone and subsequent profound immobility (Shah et al., 2025).

Automated OHCA detection therefore demands highly specialized algorithms capable of recognizing this catastrophic physiological absence while simultaneously filtering out the immense "noise" of daily living. The systems must aggressively minimize false-positive alarms triggered by motion artifacts, poor device fit, sleep-induced bradycardia, or benign physiological variations (Hutton et al., 2022; Schober et al., 2022). Multicenter research initiatives, most notably the HEART-SAFE project, have played a pivotal role in designing, developing, and validating multimodal algorithms aimed at transforming the consumer smartwatch into a reliable "digital witness" to cardiac arrest (Schober et al., 2022). The ultimate objective of these algorithms is to continuously monitor the user in the background and, upon detecting a physiological and kinematic pattern perfectly consistent with OHCA, automatically transmit a high-priority alert along with precise GPS coordinates directly to an emergency dispatch center, entirely bypassing the need for bystander intervention.

The trajectory from theoretical models and manikin simulations to actual clinical implementation has accelerated dramatically between the years 2024 and 2026. The medical literature now proudly features the first documented, peer-reviewed case reports of real-world OHCA detection by wearable devices, occurring both during vigorous physical activity and in stationary, end-of-life settings (Edgar et al., 2026; van den Beuken et al., 2026). These reports provide a crucial, undeniable proof-of-concept, shifting smartwatch-based OHCA detection from a technological hypothesis to a phase of tangible, life-saving clinical reality. Concurrently, groundbreaking advancements in artificial intelligence (AI) and deep learning models are fundamentally improving the ability of consumer hardware to distinguish genuine pulselessness from ambient signal noise (Shah et al., 2025).

Despite these extraordinary technological strides, deploying smartwatch-based OHCA detection systems at a population scale entails formidable methodological, practical, and ethical challenges. The diagnostic accuracy of optical PPG sensors is inherently vulnerable to environmental light, extreme temperatures, and, most critically, variations in epidermal melanin concentration, raising profound concerns regarding the equitable efficacy of these life-saving devices across diverse racial populations (Bent et al., 2020; Hutton et al., 2022). From the perspective of municipal emergency response systems, the threat of false-

positive alarms remains a critical bottleneck, potentially leading to catastrophic "alert fatigue" and the dangerous misallocation of already strained EMS resources (Scquizzato et al., 2020; Eversdijk et al., 2025). Furthermore, the ethical implications of continuous biological surveillance and automated data transmission require novel frameworks of patient consent (Kaye et al., 2015; Eversdijk et al., 2024). Consequently, there is an urgent need to comprehensively synthesize the current state of knowledge. Thus, the primary objective of this systematic scoping review is to provide an exhaustive analysis of the literature concerning automated OHCA detection using smartwatches, with a deep focus on diagnostic accuracy, real-world feasibility, EMS integration, and the surrounding ethical implications.

## **Methodology**

### **Study Design**

This systematic scoping review was rigorously structured and conducted in strict accordance with the PRISMA Extension for Scoping Reviews (PRISMA-ScR) guidelines. A scoping review methodology was deliberately selected over a traditional systematic review or meta-analysis because the automated detection of OHCA via commercial wearable devices represents a highly novel, rapidly evolving, and methodologically heterogeneous field of digital medicine (Hutton et al., 2022). Unlike a meta-analysis, which seeks to answer a narrowly defined clinical question with homogeneous data, a scoping review perfectly serves the methodological objective of this paper: to broadly map the available literature, identify key technological and clinical concepts, evaluate algorithmic accuracy across varying paradigms, and highlight critical knowledge gaps, particularly concerning practical EMS implementation and ethical considerations (Eversdijk et al., 2024).

### **Search Strategy**

A comprehensive, systematic literature search was executed across three primary academic databases: PubMed, PubMed Central (PMC), and the Cochrane Library. The search timeframe was purposefully restricted to publications released between January 2019 and March 2026. This specific temporal window was chosen to capture the period of intensive technological development in advanced health features of wearable devices that immediately followed the publication of major baseline clinical validations, such as the Apple Heart Study (Perez et al., 2019). The search strategy utilized a complex, iterative combination of Medical Subject Headings (MeSH) and free-text keywords, stringently connected by Boolean operators (AND, OR). The core search strings included: ("out-of-hospital cardiac arrest" OR "OHCA" OR "cardiac arrest" OR "pulselessness") AND ("smartwatch" OR "wearable technology" OR "wearable device" OR "PPG" OR "photoplethysmography" OR "accelerometer") AND ("automated detection" OR "digital witness" OR "emergency alert"). Additionally, targeted searches were conducted using specific project acronyms and device names identified during preliminary literature scanning, such as "HEART-SAFE", "CardioWatch", and "Apple Watch" (Edgar et al., 2026; Schober et al., 2022).

### **Eligibility Criteria**

The inclusion and exclusion criteria were systematically established based on the Population, Intervention, Comparison, and Outcome (PICO) framework to ensure high relevance and methodological rigor.

- **Population:** The population comprised human subjects evaluated in various clinical, pre-clinical, and non-clinical settings. This ranged from healthy volunteers participating in controlled physiological simulation models (e.g., temporary arterial occlusion to simulate pulselessness) to actual OHCA patients experiencing a cessation of circulation in real-world environments (Schober et al., 2022; Shah et al., 2025).
- **Intervention:** The evaluated intervention was defined as the utilization of commercial, off-the-shelf smartwatches or advanced prototype wrist-worn devices equipped with at least optical PPG sensors and multi-axial motion sensors (accelerometers/gyroscopes) that utilized specific algorithms to detect an absence of a pulse, a sudden fall, or prolonged physical immobility.
- **Comparison:** Where applicable, smartwatch performance was compared against established clinical reference standards, including 12-lead electrocardiograms (ECG), invasive arterial blood pressure monitoring, or formal clinical assessment by an attending EMS physician or paramedic.
- **Outcomes:** Primary outcomes of interest included standard diagnostic metrics (sensitivity, specificity, positive predictive value, negative predictive value, and area under the receiver operating characteristic curve [AUC]). Secondary outcomes encompassed technological feasibility (battery consumption, processing latency), potential for direct integration with 112/911 dispatch systems, and qualitative assessments of ethical, legal, and psychosocial implications (Eversdijk et al., 2025).

Publications exclusively focused on the detection of arrhythmias (e.g., AFib, tachycardia) that were entirely unrelated to the detection of cardiac arrest, studies utilizing contactless ambient sensors (e.g., radar,

camera-based) or implantable cardiac devices (e.g., ICDs, loop recorders), animal models, non-English publications, and conference abstracts lacking comprehensive full texts were strictly excluded. However, landmark studies regarding baseline PPG accuracy or algorithmic bias were retained if they provided essential contextual background on sensor limitations, such as the widely cited issue of skin pigmentation bias affecting optical signal fidelity (Bent et al., 2020). Given the extreme novelty of the field, peer-reviewed clinical case reports documenting the first actual real-world detections of OHCA by wearables were strictly included as they represent the highest level of current real-world evidence (Edgar et al., 2026; van den Beuken et al., 2026).

#### **Data Extraction and Quality Assessment**

Following the initial search, all retrieved records were imported into a reference management software for deduplication. The unique records then underwent a rigorous two-stage screening process: initial title and abstract screening for broad relevance, followed by a meticulous full-text review against the PICO criteria. This process culminated in a final narrative synthesis of the selected high-quality publications. Data extraction was performed using a customized, standardized charting form. Extracted variables included study characteristics (author, year, design), device hardware specifics, sensor modalities utilized, signal sampling frequencies, exact algorithmic thresholds for triggering an alarm, characteristics of the study population, diagnostic performance metrics, and author-reported limitations.

The risk of bias and methodological quality of the included studies were carefully assessed using validated tools appropriate for each specific study design. For diagnostic accuracy and simulation studies, a modified version of the Quality Assessment of Diagnostic Accuracy Studies 2 (QUADAS-2) tool was applied. The extracted qualitative and quantitative data were subsequently grouped thematically into three major synthesis domains: (1) technological foundations and algorithmic diagnostic accuracy, (2) real-world clinical application and case reports, and (3) ethical, regulatory, and socio-psychological implications.

### **Results**

#### **Technological Foundations and Physics of Detection**

The literature review revealed a robust and highly cohesive body of evidence evaluating the intricate technological feasibility of using commercial smartwatches as automated OHCA detectors (Hutton et al., 2022). The operational foundation of these life-saving systems is the continuous, non-invasive, high-frequency monitoring of both physiological and kinematic parameters. This is almost universally achieved through the multimodal fusion of reflective photoplethysmography (PPG) and triaxial accelerometry (Schober et al., 2022).

Understanding the physics of PPG is critical to understanding both its capabilities and its limitations in OHCA detection. PPG sensors on smartwatches typically emit green light (wavelengths around 500–550 nm) into the user's wrist tissue. Blood, specifically hemoglobin, is highly absorbent of green light. As the heart beats and a pulse wave travels through the arterial and capillary bed of the wrist, the volume of blood temporarily increases, causing more green light to be absorbed and less to be reflected back to the smartwatch's photodiode. By continuously measuring these minute variations in reflected light, the device generates a pulsatile waveform that corresponds directly to the cardiac cycle. In the context of OHCA, the algorithm is not looking for the presence of a specific rhythm; rather, it is searching for the absolute and sudden *flattening* of this waveform, indicating a catastrophic cessation of microvascular perfusion.

However, optical PPG alone is notoriously susceptible to corruption. Everyday physical activities, varying ambient light, and changes in vascular tone (e.g., vasoconstriction due to cold temperatures) generate substantial "noise" that can easily mimic or mask a pulse. Therefore, automated OHCA detection relies heavily on the concomitant use of MEMS accelerometers. These sensors measure proper acceleration in three-dimensional space (X, Y, and Z axes). In an OHCA scenario, the accelerometer is tasked with recognizing a highly specific kinematic signature: a sudden, uncontrolled loss of postural tone (often registering as a free-fall or sudden impact), immediately followed by absolute, prolonged macroscopic immobility.

The algorithmic architecture integrates these two distinct data streams. A standard detection protocol requires the simultaneous or highly specific sequential fulfillment of multiple criteria: a severe kinematic event (fall/immobility) paired with a sustained, verifiable absence of a PPG pulse signal. The selection of the temporal threshold defining "absence of pulse" is a delicate clinical and engineering balance. The algorithm must wait long enough to ensure the signal loss is not merely a transient artifact caused by a shifting watch strap, but act swiftly enough to preserve the patient's brain tissue. Studies associated with the HEART-SAFE project, as well as recent developments utilizing Google Pixel hardware, typically defined this critical threshold as a sustained, verified absence of a PPG signal for approximately 10 to 25 seconds, processed through advanced digital signal processing filters (Schober et al., 2022; Shah et al., 2025).

### Diagnostic Accuracy and AI Integration

Validations conducted in rigorously controlled environments have demonstrated the remarkably high efficacy of these multimodal algorithms. In advanced simulation studies, which often utilized human volunteers undergoing temporary, safe arterial occlusion (e.g., using inflated blood pressure cuffs to safely simulate pulselessness at the wrist), algorithms consistently achieved a sensitivity of approximately 98% and a specificity of 99%, with a negative predictive value approaching 99.9% (Schober et al., 2022).

Furthermore, the integration of Artificial Intelligence (AI) has marked a paradigm shift in diagnostic accuracy. A landmark 2025 publication in *Nature* demonstrated how deep learning architectures, specifically Convolutional Neural Networks (CNNs) trained on millions of hours of diverse physiological data, can be deployed directly onto the edge-computing hardware of a consumer smartwatch (Shah et al., 2025). Rather than relying on simple, hard-coded heuristic thresholds, these AI models dynamically analyze the morphology of the raw PPG waveform, effectively learning to differentiate between the chaotic signal noise of a smartwatch slipping on a sweaty wrist and the profound, absolute flatline of true circulatory arrest. These AI-driven evaluations confirmed that modern consumer smartwatches can identify sudden loss of pulse events with performance metrics robust enough to be considered for societal-scale deployment (Shah et al., 2025).

Concurrently, however, the literature clearly delineates several stubborn hardware limitations that AI alone cannot fully solve. Health equity concerns represent a profound challenge; seminal studies have demonstrated that the fundamental physics of optical PPG sensors result in inherent bias. Because green light is heavily absorbed by epidermal melanin, individuals with darker skin tones (higher Fitzpatrick skin phototypes) experience a severely attenuated optical signal reaching the vascular bed. This results in a chronically lower signal-to-noise ratio (SNR), which can degrade measurement accuracy and potentially delay or confuse an OHCA detection algorithm in populations with darker skin (Bent et al., 2020; Hutton et al., 2022). While advanced AI training datasets are being aggressively diversified to mitigate this, skin type variation remains a fundamental hurdle for optical health sensors.

### Real-World Application and Clinical Case Reports

The transition from highly controlled simulation studies to chaotic, unpredictable real-world practice marks the most critical milestone in the development of this technology. A massive breakthrough in the field was the peer-reviewed documentation of the first real-world, fully automated detection of an OHCA during rigorous physical activity. Edgar et al. reported a seminal case of a middle-aged individual who experienced a sudden cardiac arrest while actively cycling outdoors, while concurrently wearing a specialized CardioWatch device (Edgar et al., 2026).

The data logs from this device provided an unprecedented, second-by-second physiological narrative of sudden death and automated rescue. The device recorded a sequence perfectly characteristic of OHCA: an abrupt, complete loss of the pulsatile PPG signal, paired instantaneously with a chaotic kinematic signal registered by the accelerometer as the patient crashed, followed by complete stillness. Despite the intense motion artifacts inherently generated during an active cycling session, the algorithm successfully filtered the noise. After precisely 22 seconds of confirmed pulselessness and immobility, the algorithm automatically generated a critical alert, routing GPS coordinates to emergency responders. The diagnosis was subsequently confirmed upon EMS arrival via a 12-lead ECG demonstrating ventricular fibrillation (Edgar et al., 2026). This case is profoundly significant because it definitively proves the algorithm's resilience and capability to function flawlessly outside of a laboratory.

A second vital piece of real-world evidence involved the first automated detection of cardiac arrest using a widely available, commercial, device-independent consumer smartwatch (rather than a specialized medical wearable). In this case report, the smartwatch successfully detected a gradual but complete loss of the pulse signal in a stationary patient, triggering the appropriate digital response (van den Beuken et al., 2026). This proved that mass-market, consumer-grade electronics already present on the wrists of millions of citizens can effectively bridge the fatal gap between unwitnessed collapse and EMS notification.

Crucial to the practical, life-saving impact of this wearable technology is its seamless and immediate integration with municipal emergency medical services (EMS) dispatch infrastructure. Extensive geographical simulation studies and rigorous meta-analyses suggest that automated smartphone and smartwatch alerts, directly transmitting GPS coordinates and suspected cardiac arrest notifications to emergency call centers, can drastically alter patient outcomes. By instantaneously recognizing the event at the moment of collapse (time zero) and eliminating the human delay of a bystander recognizing the emergency, finding a phone, and verbally communicating location and symptoms, automated systems can significantly reduce professional response times by an estimated critical window of 4 to 7 minutes (Scquizzato et al., 2020; Semeraro et al., 2021).

Furthermore, there is a powerful, established synergy between OHCA detection by wearables and community-based first responder systems. Advanced EMS infrastructures in Europe increasingly utilize smartphone applications to silently dispatch trained, registered civilian volunteers (e.g., off-duty nurses, CPR-certified citizens) who happen to be in the immediate geographic vicinity of a suspected cardiac arrest, often directing them to the nearest public access defibrillator (AED) en route. The instantaneous activation of these volunteer networks by a smartwatch, occurring simultaneously with the dispatch of a professional ambulance, exponentially increases the likelihood that high-quality chest compressions are initiated prior to the arrival of the EMS team, thus artificially extending the patient's window of viability (Semeraro et al., 2021; Scquizzato et al., 2020).

### Discussion

The systematically synthesized literature unequivocally confirms that commercial, mass-market wearable devices equipped with advanced photoplethysmography (PPG) sensors and micro-electromechanical accelerometry algorithms have reached an unprecedented level of technological maturity. These ubiquitous consumer devices can now be legitimately positioned as viable, highly sensitive, and automated out-of-hospital cardiac arrest (OHCA) detectors (Schober et al., 2022; Shah et al., 2025).

The recent, peer-reviewed, real-world case reports provide incredibly robust, undeniable clinical evidence that these devices possess the sophisticated capacity to identify a catastrophic, instantaneous loss of systemic perfusion, recognize accompanying kinematic fall patterns, filter out intense environmental noise, and initiate rapid, autonomous emergency alerts (Edgar et al., 2026; van den Beuken et al., 2026). The primary clinical and epidemiological implication of these findings is profound: society now possesses a scalable technological tool with the absolute potential to fortify the weakest and most fatal link in the entire chain of survival—the timely recognition of unwitnessed cardiac arrest.

However, the widespread, population-level proliferation and integration of these automated alert systems into existing emergency infrastructures is not exclusively a technological or engineering issue; rather, it is a deeply complex, multi-layered socio-technical challenge. Striking a delicate and legally sound balance between the immense public health benefits of automated rescue and the fundamental rights to user autonomy, data security, and personal privacy is paramount (Eversdijk et al., 2024).

The continuous, background monitoring of highly sensitive physiological vital signs, paired with the constant tracking of precise geospatial location (GPS coordinates), constitutes a significant, unrelenting intrusion into the private sphere of the citizen. When a smartwatch algorithm suspects an OHCA event has occurred, the device must autonomously and instantaneously transmit this highly sensitive health and location data to a government or municipal dispatch center. In doing so, the device is essentially programmed to completely override immediate, explicit user consent under the legal and ethical assumption of a life-threatening medical emergency (Kaye et al., 2015).

Consequently, the literature strongly underscores the absolute legal necessity of implementing sophisticated "dynamic consent" models within the software architecture of these wearables. Dynamic consent represents a paradigm shift from traditional, static "terms and conditions" agreements. It requires providing users with highly transparent, easily modifiable, and continuously updated digital interfaces where they can granularly control their data sharing permissions. Users must have the explicit, immediate ability to temporarily pause monitoring (e.g., during intimate moments or high-risk activities where a false alarm would be exceptionally disruptive) and clearly understand exactly what data will be transmitted to whom in the event of an automated alert (Eversdijk et al., 2024; Kaye et al., 2015). Without robust dynamic consent frameworks, public trust in wearable health surveillance will rapidly erode, severely limiting adoption.

Equally critical to the viability of this technology is the systemic problem of false-positive alarms. From an engineering standpoint, detection algorithms must be aggressively tuned to achieve exceptionally high specificity (ideally exceeding 99.5%). In the context of municipal emergency response, an influx of false-positive automated alarms—triggered perhaps by a user taking off their watch and dropping it on a soft bed, or a sensor malfunctioning during intense, erratic movement—could rapidly overwhelm already strained 112/911 dispatch centers. This phenomenon directly leads to "alert fatigue" among both professional dispatchers and civilian volunteer first responders. If responders are repeatedly dispatched to "smartwatch cardiac arrests" that turn out to be false alarms, they will inevitably begin to subconsciously deprioritize these specific digital alerts, delaying response times for genuine emergencies and entirely negating the technology's life-saving potential (Scquizzato et al., 2020).

Psychosocial acceptance remains another significant, often under-researched dimension of widespread implementation. Comprehensive survey data and qualitative focus group studies conducted among diverse patient populations and practicing physicians reveal a complex landscape of attitudes. While there is universal support for the theoretical concept of a life-saving digital safety net, potential users harbor deep-seated, pragmatic concerns regarding catastrophic technological failure (the device missing a true arrest), the profound social embarrassment and potential legal liability associated with triggering a massive false alarm, and the significant, chronic psychological burden (anxiety) of being continuously, algorithmically monitored for sudden death (Eversdijk et al., 2025).

Furthermore, the paramount issue of health equity and algorithmic fairness must be aggressively and transparently addressed by device manufacturers and regulatory bodies. As explicitly demonstrated in the literature, deploying optical PPG algorithms that perform suboptimally in individuals with higher epidermal melanin concentrations (darker skin tones) due to the physics of green light absorption could inadvertently, yet severely, exacerbate existing systemic healthcare disparities (Bent et al., 2020; Hutton et al., 2022). If a life-saving technology is statistically less likely to detect a cardiac arrest in a person of color due to sensor bias, its widespread deployment becomes an urgent ethical crisis. This highlights the absolute imperative of training next-generation Artificial Intelligence and machine learning models on massive, globally diverse datasets, and legally mandating rigorous clinical validations across fully representative human populations before these features are allowed to be marketed to the public (Shah et al., 2025).

### **Conclusions and Future Directions**

In conclusion, the exhaustive synthesis of current evidence clearly indicates that commercial wearable devices, particularly ubiquitous consumer smartwatches combining high-fidelity photoplethysmography with triaxial accelerometry, have advanced sufficiently to act as highly effective, automated digital detectors for out-of-hospital cardiac arrest. By continuously monitoring the user's microvascular bed for the catastrophic loss of pulsatile flow and utilizing kinematic sensors to identify sudden, characteristic fall patterns, these remarkable devices possess the unique capability to strengthen the recognition of unwitnessed events. Unwitnessed arrests currently represent the most vulnerable, fatal link in the global chain of survival, and wearables offer the first truly scalable solution to this epidemiological crisis.

Recent, groundbreaking real-world case reports and massive, large-scale AI validations published in premier scientific journals confirm unequivocally that these complex multimodal algorithms are capable of accurately detecting true OHCA events using widely available consumer-grade hardware. They have proven their resilience against the chaotic noise of real-world environments, successfully triggering life-saving emergency chains.

However, widespread clinical application and integration into national healthcare infrastructures require urgently addressing several stubborn methodological, technical, and ethical challenges. The real-world effectiveness of optical sensors remains highly susceptible to intense motion artifacts, improper device fit, and, most troublingly, severe physiological disparities related to skin pigmentation and melanin concentration. It is absolutely critical for the survival of EMS systems to mitigate the risk of catastrophic alert fatigue by relentlessly optimizing algorithms to maintain near-perfect specificity.

Furthermore, the deployment of this continuous surveillance technology must be strictly governed by transparent, user-centric dynamic consent models that fiercely protect user autonomy and data privacy while seamlessly enabling the rapid, autonomous activation of professional and community response chains. Future research paradigms must aggressively shift away from controlled, laboratory-based technical validations toward massive, large-scale, prospective, randomized clinical trials conducted in diverse, uncontrolled, real-world populations. These future studies are essential to definitively evaluate the true, population-level impact of automated smartwatch alerts on the crucial metrics of time to CPR initiation, time to first defibrillation shock, and ultimately, survival with favorable neurological outcome to hospital discharge.

Technologically, next-generation devices must leverage highly advanced, edge-computing deep learning models trained specifically to minimize false alarms and entirely eliminate skin color biases. By addressing these critical engineering and ethical hurdles, society can ensure that this extraordinary, life-saving wearable technology is equitable, accurate, and truly accessible for all.

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