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SUDDEN CARDIAC ARREST DURING MASS RUNNING EVENTS IN THE CONTEXT OF THE 2025 EUROPEAN RESUSCITATION COUNCIL GUIDLINES AND CURRENT SCIENTIFIC EVIDENCE

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ABSTRACT

Introduction and objective: Sudden cardiac arrest (SCA) during outdoor sport training is a complication where a quick response from medical professionals is crucial for increasing chances of survival. In parallel with the global growth in running events, there is a need to implement new recommendations and technologies to improve prevention, detection, and treatment of SCA among runners.
Review Methods: A comprehensive literature review was conducted, analyzing studies indexed in PubMed, Google Scholar, and the official ERC Guidelines from 2021 and 2025.
Key findings: Recent data suggest that, although the number of SCA cases in mass running events has remained relatively stable over the past decade, running-related deaths have declined. These outcomes are likely attributable to significant improvements in emergency action planning, widespread AED availability, and enhanced first-aid education. There are also new ideas that can further improve those outcomes, not only in treatment but also in SCA prophylaxis. New preventive and diagnostic strategies, such as point-of-care blood gas analysis (POC BGA) and risk-profiling patient triage, focus primarily on early triage and smartwatch pulse-detector systems, offering a new perspective on more rapid detection of SCA during outdoor activity. Advances in treatment focus on optimizing the prehospital chain of survival through mobile AED teams, GPS-enabled responder coordination, and structured "field-of-play" protocols. Further research is needed to reduce the time to defibrillation and improve neurological outcomes during endurance events.

KEYWORDS

Sudden Cardiac Arrest, Running, Marathon, Endurance Events, Automated External Defibrillator, Bystander CPR

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Introduction

Sudden cardiac arrest (SCA) occurring during endurance running events is a medical incident that needs to be managed immediately. However, when SCA occurs, especially during large-scale events with many participants, numerous obstacles can lower the standard of patient care, and limited resources may pose challenges during mass events.

Nowadays, an increasing number of people are picking up running as a form of recreational sport, and we observe increasing popularity in races - marathons, half-marathons, ultra-marathons, and other events. Running may be an effective way to improve health and reduce the risk of hyperlipidemia, hypertension, visceral obesity, hyperglycemia, and insulin resistance (Ruegsegger & Booth 2018). But like every other sport activity, there can be individuals who will develop serious complications from exercising, and one of the most tragic, if not the most, may be a sudden cardiac death during training. Although the overall incidence of SCA during long-distance races remains low, its dramatic presentation and potential low chances of return of spontaneous circulation (ROSC) have driven extensive research into early recognition, rapid response systems, and preventive strategies because our role as medics is not only to treat our patients, but also to prevent illnesses so that we can minimize number of patients needing immediate help.

Extensive analyses of marathon events have shown that quick bystander cardiopulmonary resuscitation (CPR) and rapid defibrillation are the strongest predictors of survival. In these studies, survival rates were 80% when defibrillation occurred within the first few minutes after collapse (Kim et al. 2025). These findings have reinforced the critical importance of on-site automated external defibrillators (AEDs) and well-organized emergency response systems during endurance events.

In recent years, we have observed an increasing number of innovations aimed at improving outcomes after SCA in runners. Some of them are mobile AED systems, smartwatch technologies, drone systems, and structured emergency medical coverage tailored to mass events, such as course layout and participant density.

The latest ERC 2025 guidelines highlight the importance of recognizing sudden cardiac arrest, immediately initiating chest compressions, and providing rapid access to defibrillation in public spaces. (Lott 2025) When combined, these innovations indicate a shift toward more efficient event-planning and rapid-intervention models. In this review, we summarize recent advances and ideas in the prevention, diagnosis, and treatment of sudden cardiac arrest among runners. We focus on data that may bring real-life implications for race organizers, clinicians, and emergency medical systems.

Methodology

A comprehensive literature review was conducted, analyzing studies indexed in PubMed, Google Scholar, and the official ERC Guidelines from 2021 and 2025 to find and summarize new advances in the prevention, diagnosis, and management of sudden cardiac arrest in runners, with particular emphasis on new data and practical implications for race organizers and emergency medical services.

Results

Epidemiology

Chances of sudden cardiac arrest in runners are relatively low, which used to be the reason for the long response time of medical services. Today, the incidence of cardiac arrest during marathons and half-marathons has remained relatively stable since 2010, compared with 2000-2009. The risk of dying from cardiac arrest during long-distance running races has decreased by approximately 50% compared with 2000-2009. (Kim et al. 2025) That means that effective emergency action planning during marathons and half-marathons, with immediate access to defibrillation, has led to notable improvements in SCA outcomes, comparable to settings with publicly accessible automated external defibrillators (Kim et al. 2025).This indicates that improving the distribution of defibrillators and emergency planning enhances safety during mass sport events.

In a study made by Kim et al. (2025), cardiac arrests remained more common among men (1.12 per 100 000 [95% CI, 0.95-1.32]) than women (0.19 per 100 000 [95% CI, 0.13-0.27]) and during the marathon (1.04 per 100 000 [95% CI, 0.82-1.32]), compared with the half-marathon (0.47 per 100 000 [95% CI, 0.38-0.57]). Among runners for whom a definitive cause of cardiac arrest could be determined (n = 67/128 [52%]), coronary artery disease rather than hypertrophic cardiomyopathy was the most common etiology.

This data is consistent with other researchers' conclusions that, as we read in other studies, more than 80% of sudden cardiac arrest causes in athletes have a cardiovascular origin, primarily from inherited cardiac conditions in young athletes and coronary artery disease (CAD) in older ones.

Recent studies using post-mortem examinations show that there is an increasing number of cases of sudden cardiac death involving hearts with normal anatomy and physiology (with the most likely suggestion of the causes of these deaths being dysautonomia, sudden arrhythmia, and primary arrhythmia) (Harmon, Drezner, Wilson & Sharma 2014; Dostal, Hybska, Saganelidze, Pudil & Stasek 2024; Marijon et al. 2011).

Novelties in prophylaxis

Risk group profiling

A major recent shift in preventing sudden cardiac arrest (SCA) in runners is moving from "universal screening" toward risk profiling, i.e., identifying subgroups in whom additional evaluation or intensified risk-factor management is most likely to be beneficial.

For older athletes, a medical evaluation of individual risk should include assessment of cardiovascular, renal, and metabolic diseases; current level of physical activity; presence of signs or symptoms suggestive of cardiovascular problems; and the desired level of physical activity. (Armstrong, Paternostro-Bayles & Conroy 2018) In this context, medical screening should be adapted to the risk profile of the target population. (Manabe, Kato & Yamasawa 2024; Tanaka et al., 2022). This topic requires further investigation, and in the future, it may be possible to summarize potential contraindications for runners considering race participation.

Emergency Point-of-Care Blood Gas Analysis - a case from Vienna City Marathon

Point-of-care blood gas analysis (POC BGA) is a diagnostic innovation used for preventive triage before the Vienna City Marathon 2023, and it was described in a study made by Brock et al. in 2025. At the race, multiple medical stations were available where participants could have this test performed.

The technology provided rapid, real-time measurements of key metabolic and physiological parameters—including pH, lactate, creatinine, and electrolytes—enabling clinicians to distinguish benign exertional symptoms from markers of significant metabolic stress that may indicate a higher risk of medical emergency during a race. The authors of this study stated that the main serum parameters to monitor were elevated lactate concentrations and acid-base imbalances, as these could indicate disproportionate physiological strain and may identify patients at higher risk of collapse or SCA during the race.

Although the study recorded no cases of cardiac arrest during the event, the use of POC BGA enriched the clinical picture beyond traditional vital signs, thereby strengthening clinical decision-making regarding triage, hospital transfer, and safe on-site discharge (Brock et al. 2025). As such, POC BGA represents an innovative step toward enhanced preventive assessment by facilitating objective, rapid evaluation of runners' internal metabolic state in real time—potentially before the onset of critical deterioration or sudden cardiac events.

However, as noted in the study, it is not recommended that blood gas analysis be performed on every patient; further studies are needed to evaluate this approach. In the meantime, we can identify specific selection criteria to use POC BGA in more sport-related mass events. The authors of the study that took place in Vienna established 3 examples of patients who may be considered for POC BGA before starting a sports event:

„-Patients in (semi-)critical condition to further assess the severity of impairment and to establish a basis for an early decision to hospitalize.

-Patients with multiple or profound medical conditions are required to create a more complete picture of the comorbid patient and aid further treatment.

-As decision support for early discharge on-site without further workup." (Brock et al. 2025, p.8)

Although emergency point-of-care blood gas analysis may not seem to be a form of prophylaxis, we included it in this section of the article because abnormal blood gas parameters can indicate a future cardiac arrest in marathon participants. It is a creative and interesting idea that, in our opinion, warrants investigation to identify specific indicators of a possible cardiac event and to prevent certain individuals from participating in sport-related events. In this way, it can serve as an advanced preventive method in the future.

Novelties in diagnostics

Smartwatches as a novelty in cardiac arrest detectability

Given that running is an outdoor sport and runners spend most of their activity time outside, often with no hospital in reach, cardiac arrest could occur in a scenario with no witnesses. The rising popularity of cross-country running could be a significant risk factor for

unwitnessed accidents, including cardiac arrest. In both situations, the reaction time and the initiation of rescue actions should not be delayed.

A well-established feature of smartwatches is pulse detection. It is often promoted as a means of improving health awareness and enhancing sports performance. While widely available applications provide a variety of sensors that can detect pulse pattern characteristics, none were designed or approved to detect cardiac arrest. In 2024, Google launched a loss-of-pulse detection feature on the Pixel Watch 3 (Scquizzato,Landoni,Consolo & Scandroglio 2024). This may be a breakthrough in cardiac arrest detection via smartwatches, as it may reduce the time between cardiac arrest and alerting medical providers. Approximately a four-minute delay occurs in the event of a witness's cardiac arrest. (Herlitz et al. 2015) Moreover, it could help in case of unwitnessed cardiac arrest, which constitutes up to 50 % of out-of-hospital cardiac arrest (OHCA). (Marijon et al. 2022)

In 2025, Dutch scientists reported results from a self-developed application, The HEART-SAFE (Home Emergency Alerting and Response Technology–Survive A Fatal Event), involving 19 participants (van den Beuken et al. 2025). They developed a Wear OS application that integrates with the smartwatch and runs on both iOS and Android. The aim is to establish a system in which potential cardiac arrests are reported directly via their app to a national emergency system.

The HEART-SAFE app reported a delay of 30 s between cardiac arrest occurrence and notifying medical providers. This is a substantial reduction in time relative to the average 4-minute delay in notifying medical providers in witnessed OHCA cases.

The delay of the Dutch app consists of 5 seconds for pulse analysis and alarm triggering, and 20 seconds for the application user to call off a false alarm. The rate of false alarms was 1,4 per patient per 24 hours. At first glance, this number may not appear relevant; however, given a possible widespread use of this application, the number of false alarms could be exponential, thereby causing paralysis of the Emergency system.

Novelties in the Treatment Strategies

SCA during outdoor sports requires prompt intervention to ensure survival. Recent studies have shown that the most effective ways to improve survival are rapid CPR, rapid bystander response, and the availability of an AED (Chen et al. 2019; Marijon et al. 2015).

For athletes with shockable rhythms, a medical team should deliver at least three shocks on the field, then transfer the patient to a previously designated medical emergency point if the rhythm persists. (Lott et al. 2025)

This requires advanced planning of event logistics and may indicate an excessive need for exercises and medical simulation training for medical professionals who cover such events.

Mobile AED Systems

An idea already used in some mass-running events is the deployment of mobile AED systems. This medical response model is based on a coordinated network of medical professionals. This includes mobile teams (pairs of paramedics equipped with automated external defibrillators (AEDs) and emergency medical kits) who patrol the course by bicycle, and on-foot teams (pairs of paramedic trainees capable of providing basic life support and early defibrillation). This structure is further supported by medical dispatchers, staff at designated first-aid stations, and physician volunteers, who can be contacted via GPS-enabled communication systems when necessary. (Kinoshi et al. 2018). This model requires advanced planning, but the results may surprise.

In an observational study by Tomoya Kinoshi et al., 30 cases of sudden cardiac arrest occurring during mass running events between 2005 and 2017 were analyzed; all were managed using mobile AED systems. Among the 28 witnessed arrests, cardiopulmonary resuscitation was initiated extremely rapidly, with a median time of less than one minute from collapse. At the same time, the first defibrillation shock was delivered at a median of just over 2 minutes, which is really hard to achieve in other conditions. Ventricular fibrillation treated with defibrillation was the leading cause of SCA, and a smaller number of runners achieved ROSC following basic life support alone. The median time from collapse to ROSC was under 6 minutes. Importantly, all affected runners achieved ROSC on site and demonstrated favorable neurological outcomes at both short- and long-term follow-up. (Kinoshi et al. 2018). These outcomes are almost impossible to achieve with standard medical coverage for running events.

AED Drones

Mobility in crowded areas may be severely limited, as our ability to move largely depends on available transportation options. Evolving technology, such as AEDs carried by drones, discussed at the ESC 2025 Resuscitation Council Congress in Rotterdam could shorten transportation time. The idea is that emergency medical dispatchers could send a drone carrying an AED directly to a person who called the emergency number. Drones would have GPS and tracking systems. Also, they would be equipped with camera systems and an integrated „sense and avoid" system to prevent collisions.

An interesting study on this topic was conducted in Aalborg, Denmark, in 2023.The purpose of this study was to test newly developed drone systems that would deliver defibrillators directly to patients in need of care and to determine whether these systems would be more efficient than standard EMS coverage.The drone platform was linked to the Emergency Medical Dispatch Call Centre (EMDCC). The dispatchers were able to trigger the system automatically without additional interventions. After activation, the drone's system performed system and safety diagnostics, selected an appropriate flight trajectory (using data from the dispatch centre), and evaluated meteorological conditions before launch. If all

operational criteria were satisfied, the drone was released from its base and flew along a predefined route designed to limit flight time, particularly in densely populated urban areas (Jacobsen et al. 2025). Over the observation period, 76 emergency calls were classified as suspected OHCA (out-of-hospital cardiac arrest), 49 of which occurred while the drone system was activated. Of the 49 cases of suspected out-of-hospital cardiac arrests, 16 (33%) met the eligibility criteria for drone deployment. In each case, the drone successfully transported an AED to the scene. The drone reached the scene with a median response time of 4 minutes and 47 seconds (IQR 3:45–5:27), whereas the median ambulance arrival time in these cases was 3 minutes and 25 seconds (Jacobsen et al. 2025). Despite adverse weather conditions, technical problems, and the technology's limited development, we consider this an interesting idea that warrants further investigation.

Optimising education and time of reaction as a form of treatment

Time is one of the most important, if not the most important, factors in resuscitation outcomes. As a result, innovations in this area of medicine focus on developing methods to expedite patient arrival. And as we know, in adult resuscitation, the most common cardiac rhythms that require CPR are shockable rhythms.

A study by Bohm P. et al. found that only public AED use before EMS arrival was associated with significantly higher survival rates. In a study group in which all cases involved bystander CPR and AED use, 10 of 11 patients survived, and the hospital discharge rate was 90.9%. (Bohm et al. 2023)

That indicates that another essential aspect is health education for event participants. Bystander education can be improved by offering first-aid courses to participants in mass sporting events and by spreading knowledge in other forms.

The new ERC 2025 guidelines highlight the importance of education and suggest the use of simulation-based resuscitation education and technology-enhanced learning (TEL). Still, in low-resource areas, it is recommended to consider organizing first-aid courses even without technological or educational resources, for example, by using low-cost (self-made) manikins so that this knowledge can be used everywhere in the world despite cost constraints. (Nabecker et al. 2025).

Discussion

As we know, sudden cardiac arrest (SCA) during running events is a serious situation that needs to be handled immediately. Especially in the context of mass-participation races, where logistical constraints, crowd density, and limited immediate access to medical care may delay life-saving interventions, we face the challenge of developing new approaches to improve patient care. Recent years brought a broader understanding of the epidemiology, mechanisms, and determinants of survival following SCA in athletes. Available studies indicate that, although the incidence of SCA during marathons and half-marathons has remained relatively stable since 2010, mortality associated with these events has decreased markedly compared with earlier decades. This improvement is strongly linked to improved emergency action planning, the widespread availability of automated external defibrillators (AEDs), rapid bystander cardiopulmonary resuscitation (CPR), and prompt defibrillation. SCA in runners occurs more frequently among marathon participants than in participants in other running races. The group with the highest risk of SCA in running events is male, older athletes. Coronary artery disease is the most common underlying cause in older runners, while inherited or primary arrhythmic conditions remain relevant in younger athletes. These findings indicate a shift from universal approaches toward targeted risk profiling and individualized prevention strategies, consistent with

the updated ERC 2025 recommendations. There are also new findings in SCA prevention, such as point-of-care blood gas analysis (POC BGA). Another critical advance is technology such as smartwatches with loss-of-pulse detection and experimental emergency alerting applications, which represent promising yet still evolving solutions for reducing delays in recognizing cardiac arrest, particularly at outdoor events. Regarding innovations in managing outdoor SCA, studies indicate increased use of technologies, such as mobile AED drone systems, with promising outcomes in tests. To optimize patient care, we also need better education systems for healthcare professionals and event participants.

Conclusions

A combination of rational use of new technologies in emergency medicine, advanced event-planning strategies, and patient triage may substantially improve patient outcomes in the management of sudden cardiac arrest during mass running events.

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