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Physical Training in ICD Patients: Safety, Clinical Results, and Quality of Life Improvements

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ABSTRACT

Background: Implantable cardioverter-defibrillators (ICDs) represent the most effective therapy for the prevention of sudden cardiac death in patients at high risk of malignant ventricular arrhythmias. Despite their proven survival benefit, many patients limit physical activity due to fear of arrhythmia or device shocks, which may negatively affect functional capacity and quality of life.

Aim: The aim of this study was to summarize current evidence on the safety of exercise training in patients with ICDs and to analyze the impact of device therapy on patients' physical activity levels.

Material and Methods: A PRISMA-compliant literature review was conducted via PubMed, focusing on studies published between 2021–2026. Keywords included "ICD," "exercise training," "safety," "shock," and "quality of life." Specific case reports were included to provide insights into unique clinical interactions and the impact of exogenous substances.

Results: Available evidence, including randomized controlled trials and meta-analyses, indicates that moderate aerobic exercise and structured cardiac rehabilitation programs are safe in ICD recipients and do not significantly increase the risk of ventricular arrhythmias or ICD shocks. The incidence of shocks during exercise is very low. However, experiencing ICD shocks is associated with a significant decline in daily physical activity and increased anxiety, whereas antitachycardia pacing (ATP) does not produce similar behavioral effects. Regular exercise improves cardiorespiratory fitness (VO_2peak), autonomic modulation, and quality of life.

Conclusions: Current evidence supports appropriately prescribed and supervised exercise training as a safe and beneficial component of comprehensive care in patients with ICDs. Current evidence suggests that sedentary recommendations are often unjustified, while individualized risk assessment and optimal device programming remain essential.

Keywords Cardiac rehabilitation; Exercise training safety; Kinesiophobia; High-Intensity Interval Training (HIIT); Health-related Quality of Life (HRQoL); Implantable cardioverter-defibrillator (ICD); Patient safety management; Risk Management in Sport; Safety Protocols; Physical training

INTRODUCTION

Sudden cardiac death (SCD) remains one of the leading causes of cardiovascular mortality worldwide. Implantable cardioverter-defibrillators (ICDs) represent the most effective strategy for preventing arrhythmic death by detecting and terminating life-threatening ventricular arrhythmias through antitachycardia pacing (ATP) or high-energy shock delivery [1].

ICDs are widely used for both primary prevention in patients with significantly reduced left ventricular ejection fraction and secondary prevention in individuals with a history of ventricular tachyarrhythmias or cardiac arrest. Over the past decades, implantation rates have steadily increased, and contemporary devices incorporate advanced rhythm discrimination algorithms and sensors capable of continuously monitoring patient physical activity [2].

While the primary goal of ICD therapy is the prevention of arrhythmic death, increasing attention is being directed toward minimizing the overall treatment burden associated with the device. This burden includes not only technical complications but also psychological consequences such as anxiety, depression, and reduced quality of life following device therapies [3].

ICD shocks, although life-saving, are often perceived by patients as distressing events. Evidence from studies such as the EMPIRIC trial has demonstrated that the experience of a shock is associated with a significant decline in daily physical activity, whereas antitachycardia pacing (ATP), which is usually painless, does not produce a comparable behavioral effect [4]. These findings highlight that the type of ICD therapy may influence not only clinical outcomes but also patient behavior and lifestyle.

Regular physical activity is a cornerstone of cardiovascular disease management, particularly in patients with heart failure. Exercise training has been shown to improve peak oxygen uptake (VO_2peak), enhance functional capacity, and reduce hospitalization risk while improving overall quality of life [5,6,7,8]. Consequently, cardiac rehabilitation programs are recommended as an evidence-based component of comprehensive heart failure management [9].

Despite these well-documented benefits, many patients with ICDs limit their physical activity due to fear of triggering arrhythmia or receiving an ICD shock. Psychological distress following implantation is common, and approximately one-fifth of patients develop clinically relevant symptoms of anxiety or depression, which may contribute to avoidance of physical exertion and reduced quality of life [3].

However, accumulating evidence indicates that supervised, moderate-intensity exercise training is safe in ICD recipients and does not significantly increase the incidence of device therapies or ventricular arrhythmias [5,7,10]. Moreover, regular exercise may improve autonomic balance, increase heart rate variability, and enhance parasympathetic activity, which may contribute to greater electrical stability of the myocardium [11,12,13].

Modern ICD systems equipped with integrated activity sensors provide an objective means of assessing daily physical activity levels and monitoring behavioral changes over time [2]. These device-derived data have been shown to correlate with clinical outcomes and may serve as an important marker of prognosis in patients with cardiac implantable electronic devices [14,15].

Taken together, contemporary management of patients with ICDs should extend beyond arrhythmia termination and incorporate strategies aimed at maintaining physical activity, minimizing shock burden, addressing psychological barriers, and promoting participation in structured cardiac rehabilitation programs [5,7,8,10]. The evolution of ICD therapy therefore reflects a shift from a purely life-saving intervention toward a broader, patient-centered approach focused on long-term functional and psychological well-being.

Pathophysiological Response to Exercise in Patients with Implantable Cardioverter-Defibrillators (ICD)

Neurohormonal and Autonomic Response

In patients with an Implantable Cardioverter-Defibrillator (ICD), who frequently suffer from Heart Failure (HF) or underlying cardiomyopathies, the cardiovascular response to physical exertion deviates significantly from physiological norms. Exercise triggers a rapid surge in catecholamines (epinephrine and norepinephrine). In patients with an arrhythmic substrate—such as Brugada Syndrome or Arrhythmogenic Right Ventricular Cardiomyopathy (ARVC)—this catecholamine surge can shorten cardiomyocyte refractory periods, facilitating early afterdepolarizations (EADs) [16]. Conversely, systematic isometric and endurance training plays a vital role in the modulation of Heart Rate Variability (HRV). This is crucial for electrical heart stabilization, as regular training may lower resting sympathetic tone, thereby exerting a protective anti-arrhythmic effect [13].

Myocardial Remodeling and the Arrhythmic Substrate

Physical activity induces structural changes that may be detrimental in specific pathologies. In children and young adults with ARVC, high-intensity exercise may mechanically "stretch" weakened intercellular junctions (desmosomes) *(For specific exercise limitations in ARVC, see Table 1).* Mechanical stress leads to accelerated cardiomyocyte apoptosis and subsequent fibrofatty replacement. This remodeling creates a potent reentry substrate, significantly increasing the risk of life-threatening arrhythmias and subsequent ICD therapies [17, 38]. In the context of HF, ICD recipients often exhibit reduced functional capacity. The pathophysiology involves not only limited cardiac output but also impaired peripheral perfusion of skeletal muscles, manifesting as a significantly reduced peak oxygen uptake (VO_2peak). It is noted that while beta-blockers and device therapies (ICD/CRT) improve survival, they do not inherently improve VO_2peak levels [18]. Advanced echocardiographic techniques further refine our understanding of the arrhythmic substrate. As demonstrated by Rakesh et al. [15], 3D speckle tracking echocardiography reveals specific strain patterns in hypertrophic cardiomyopathy (HCM) patients that correlate with sudden cardiac death risk markers. Integrating such imaging data allows for more precise risk stratification, ensuring that exercise prescriptions are tailored to the individual's structural and electrical profile [36, 38, 39].

Respiratory Gas Kinetics and Functional Capacity (VO_2peak)

The parameter VO_2peak serves as a critical pathophysiological indicator for ICD patients. Exercise in these individuals is often characterized by reaching the anaerobic threshold prematurely. In patients with Congenital Heart Disease (CHD) and ICDs, low VO_2peak values during Cardiopulmonary Exercise Testing (CPET) are potent predictors of severe arrhythmic events. Increased age and low VO_2peak have been identified as independent risk factors for life-threatening arrhythmias during a three-year follow-up.

A systematic review and meta-analysis [37] confirms that reduced functional capacity is significantly associated with an increased risk of adverse events, highlightingVO_2peak as a critical marker for both risk stratification and the monitoring of rehabilitative efficacy

Despite certain limitations, these markers are capable predictors for severe arrhythmia and should be integrated into Sudden Cardiac Death (SCD) risk stratification [19].

Exercise-Induced Arrhythmia and Device Interference

Physiological heart rate increases during intensive training (e.g., HIIT) may encroach upon programmed ICD detection zones. While modern discrimination algorithms (e.g., in S-ICDs) aim to differentiate sinus tachycardia from ventricular arrhythmias, the risk of inappropriate shocks increases during rapid rhythm transitions [20,21]. Moreover, the incidence of shocks during exercise does not appear to be significantly higher than during daily activities in many patient populations [18, 50]. Intensive exertion leads to metabolic acidosis and fluctuations in potassium concentrations. These changes lower the ventricular fibrillation (VF) threshold, especially in patients with channelopathies such as Long QT Syndrome (LQTS) [22,23]. *(Detailed safety considerations for LQTS are summarized in Table 1).*

Device-Specific Interactions: S-ICD and CRT-D

In young, active patients with subcutaneous ICD (S-ICD), exercise is associated with the risk of T-wave oversensing due to EKG morphology changes during tachycardia, which may lead to inappropriate shocks [20]. In HF patients, an upgrade to Cardiac Resynchronization Therapy (CRT-D) improves the pathophysiological response to exercise by coordinating ventricular contraction, resulting in higher VO_2peak and better exercise tolerance [24].

Impact of Exogenous Substances - case report

The pathophysiology of exercise can be drastically destabilized by performance-enhancing substances. A case report of an 18-year-old athlete using kratom and caffeine prior to football training demonstrated that these substances, combined with physical exertion, lead to critical QT interval prolongation and VF through the blockade of hERG potassium channels [26].

Clinical Safety of Exercise Interventions in ICD Patients

A significant clinical misconception has historically limited the prescription of exercise for ICD recipients due to the perceived risk of malignant arrhythmias [1, 2, 50]. However, large-scale evidence, including the landmark HF-ACTION (Heart Failure: A Controlled Trial Investigating Outcomes of Exercise Training) study, demonstrated that supervised exercise training is safe. The trial showed no significant increase in all-cause mortality or hospitalization rates in patients with heart failure and ICDs who participated in structured exercise programs compared to usual care [5]. Furthermore, comprehensive meta-analyses have confirmed that exercise training does not significantly escalate the risk of mortality or heart failure-related events, reinforcing the role of physical activity as a safe therapeutic adjunct [5,7]. The safety of these interventions is not limited to simple aerobic activity; combined training programs incorporating aerobic, strength, and flexibility exercises are equally safe and effective, provided they are structured within a professional cardiac rehabilitation framework [41].

The risk of ICD discharges (both appropriate and inappropriate) during physical exertion remains a primary concern for clinicians. Data from major meta-analyses provide a reassuring statistical profile. The incidence of ICD shocks during supervised exercise sessions is remarkably low, estimated at approximately 0.9% per patient-year [5]. This indicates that the vast majority of exercise-induced tachyarrhythmias either do not occur or are managed by the device without the need for high-voltage shocks [5]. Meta-analytical data [7] suggest that while exercise may slightly increase the heart rate, it does not lead to a statistically significant rise in inappropriate shocks, provided that device detection zones are appropriately programmed and discrimination algorithms are active.

Evidence from systematic reviews and randomized controlled trials (RCTs) highlights that patients in training groups do not experience a higher burden of adverse events compared to sedentary control groups. Participation in structured cardiac rehabilitation programs has been associated with a trend toward reduced heart failure-related hospitalizations, likely due to improved cardiovascular conditioning and autonomic balance [5]. Long-term follow-up across various studies indicates that the safety of exercise extends beyond the supervised phase, provided the intensity remains within the limits established during initial Cardiopulmonary Exercise Testing (CPET).

Safety is significantly enhanced when the ICD's "Tachycardia Detection Zone" i is set at a rate at least 20 bpm higher than the peak heart rate achieved during exercise. This minimizes the crossover between physiological sinus tachycardia and the device's intervention threshold [49].

The safety of high-intensity activity has been further reinforced by the prospective LIVE-LQTS study [47]. Results indicate that athletes with Long QT Syndrome (LQTS) who adhere to expert treatment plans do not experience a higher rate of severe cardiac events during competitive sports compared to those engaging in low-intensity activity. This landmark evidence suggests that with appropriate ICD programming and clinical oversight, the spectrum of permissible physical activities for inherited channelopathy patients is broader than previously clinical guidelines suggested. Furthermore, concerns regarding the mechanical integrity of the device during more vigorous activities are being addressed by new experimental data. Wegner et al.

[45] demonstrated in an experimental model that transvenous cardiac implantable electronic devices (CIEDs) are remarkably resilient and can withstand the physical rigors associated with contact sports. This suggests that the risk of lead displacement or generator damage from blunt chest trauma may be lower than previously assumed, potentially allowing for a more flexible approach to recreational contact activities.

Current research emphasizes that physical activity is not only safe but also beneficial for most ICD recipients. The consensus remains that with appropriate device programming and patient selection, the risk of serious complications during exercise is minimal [14, 50]. While supervised programs show an high safety profile, the transition to home-based, unsupervised exercise requires careful telemetric monitoring or self-monitoring to maintain the same safety profile. the integration of remote monitoring (RM) serves as a continuous "safety net," allowing clinicians to monitor device-derived data and ensure that the patient remains within safe physiological limits during their daily activities [10, 42].

Behavioral Impacts of Device Therapies

The psychological and behavioral response of a patient to their ICD is heavily dictated by the type of therapy delivered by the device. Understanding the biopsychosocial impact of these interventions is essential for maintaining patient mobility and long-term adherence to exercise.

High-voltage shocks are inherently traumatic events. Clinical data, including the EMPIRIC trial and observational studies, demonstrate a clear correlation between ICD shocks and a significant decline in daily physical activity [4, 5]. Recurrent shocks are associated with post-traumatic stress disorder (PTSD), anxiety, and "kinesiophobia" (fear of movement). Patients who experience multiple discharges often show a marked decrease in activity levels—up to 34%—as they begin to associate physical exertion with the painful stimulus of a shock [4, 7]. Recent evidence from the SafeHeart substudy [43] further clarifies this relationship, suggesting that a measurable decrease in physical activity and disturbances in sleep patterns, captured via wearable accelerometers, can actually precede and predict appropriate ICD interventions. Moreover, behavioral shifts are not only triggered by shocks but can be influenced by external stressors; for instance, Olsson et al. [46] observed significant reductions in physical activity during national holidays, which may exacerbate the risk of fluid accumulation and heart failure decompensation in CIED recipients.

While heart failure treatments are effective regardless of a patient's frailty status, the psychological burden of device therapy may disproportionately affect those with higher frailty, necessitating more personalized support during cardiac rehabilitation [40]. To counteract this, structured and supervised exercise interventions are essential, as they help patients regain "cardiac confidence" and decouple the association between physical exertion and the fear of arrhythmic events [5, 24]

Antitachycardia Pacing (ATP) - a Behaviorally Superior Strategy

In contrast to shocks, Antitachycardia Pacing (ATP) is a painless, low-voltage therapy that terminates ventricular tachycardia (VT) without the patient typically perceiving the intervention.

ATP does not carry the same psychological burden as a shock. Because it is usually imperceptible, it does not inhibit the patient's willingness to engage in physical training. ATP is helping to preserve Quality of Life (QoL)

"ATP-centric" programming—where the device is set to attempt multiple rounds of pacing before delivering a shock—is a behaviorally superior strategy. It minimizes the risk of exercise-limiting trauma and is essential for keeping the patient physically active and socially integrated [20, 21]. This approach is particularly effective when combined with Remote Monitoring (RM) [10], which allows for the early detection of VT episodes that are successfully terminated by ATP, enabling clinicians to adjust therapy before a shock becomes necessary.

Furthermore, as emphasized by Dougherty et al. [5], educating patients about the difference between these therapies and the protective role of ATP can significantly reduce kinesiophobia and improve adherence to cardiac rehabilitation programs. Regular engagement in structured exercise, even in patients with complex substrates like hypertrophic cardiomyopathy [15, 20], is safer and more sustainable when the device is programmed to prioritize these painless interventions.

Physiological and Clinical Efficacy of Exercise Training

The clinical benefits of structured exercise in the ICD population extend beyond simple conditioning, impacting long-term survival and mental health.

The primary physiological hallmark of successful exercise intervention is the improvement in Peak Oxygen Consumption (VO_2peak). Even modest improvements in aerobic capacity translate into a reduced risk of heart failure-related hospitalization and all-cause mortality [18, 19].

Structured training enhances stroke volume, improves skeletal muscle oxidative capacity, and optimizes peripheral oxygen extraction, effectively counteracting the pathophysiological limitations of heart failure [18, 24]. These peripheral adaptations are particularly significant in ICD recipients, as they allow for an increase in VO_2peak even when central cardiac output remains partially constrained by the underlying pathology [5].

Systematic supervision in exercise programs, as highlighted by Dougherty et al. [5], not only improves physical parameters but also significantly bolsters patient confidence in the device. By providing a safe environment, clinicians can mitigate exercise-induced anxiety and the fear of shocks, which are primary barriers to physical activity. For patients with advanced heart failure, including those supported by ventricular assist devices (VAD), structured rehabilitation has been shown to be both feasible and effective in enhancing functional capacity [48]. Furthermore, a patient's frailty status should not be a barrier to active treatment or exercise [44]. Their research suggests that psychological and functional improvements are attainable across diverse patient profiles, reinforcing the principle that exercise prescriptions should be tailored to individual resilience rather than restricted by age-related vulnerability. (*The synthesis of exercise recommendations for specific cardiac substrates is summarized in Table 1).*

Adherence and the "Dose-Response" Relationship

The efficacy of training is strictly dependent on patient adherence. Research, including studies by Dougherty et al. [25] , highlights the importance of consistency in both supervised and home-based settings (e.g., daily walking programs). The integration of remote monitoring (RM) can further support this process by allowing clinicians to track patient status and device function in real-time [10, 31]. Patients demonstrating high adherence (typically >80 % of prescribed sessions) achieve clinically significant gains in cardiorespiratory fitness .However, as noted by Alharbi et al. [40], objective measures like accelerometry are more reliable than self-reported data in assessing true adherence during cardiac rehabilitation. Long-term adherence to moderate activity, such as walking, has been shown to stabilize the autonomic nervous system and reduce the frequency of arrhythmic events over time [5]. While moderate walking is beneficial, research by Auld et al. [42] suggests that more intense physical activity may lead to even more significant improvements in heart failure symptoms. This safety profile is further supported by Squeo et al. [24], who demonstrated that combined aerobic and strength training does not increase the risk of inappropriate ICD interventions, thereby addressing a common psychological barrier to exercise.

Psychological Well-being and Quality of Life (QoL)

Beyond the objective physiological data, physical activity acts as a potent non-pharmacological intervention for mental health in the ICD population. The psychological burden of living with the constant risk of life-threatening arrhythmias often leads to significant emotional distress, which exercise can effectively mitigate.

Systematic training is associated with a marked reduction in anxiety and depression scores, which are highly prevalent in the post-implantation period. Exercise helps break the cycle of fear-avoidance, where patients limit activity due to a perceived risk of triggering an event [13].

Clinical data from the EMPIRIC study [4] explicitly shows that while shocks correlate with a drastic decline in daily activity, patients receiving ATP maintain their baseline levels of movement. This preservation of physical activity is a key factor in maintaining long-term Quality of Life (QoL) [3, 4].

Regular, safe exercise helps patients regain "cardiac confidence." This psychological shift allows them to reframe their perspective, viewing the ICD not as a restrictive limitation, but as a reliable protective mechanismthat enables, rather than hinders, an active and fulfilling lifestyle [5,13].

Participation in supervised exercise programs or community-based activities (e.g., walking groups) reduces the sense of social isolation often felt by patients with complex cardiac histories, further enhancing overall Quality of Life [3, 5].

Practical recommendations for ICD patients

Patients with an implantable cardioverter-defibrillator (ICD) often avoid physical activity due to fear of arrhythmia exacerbation or ICD shocks. However, exercise training can be safely performed when appropriate precautions are followed.

Training intensity should be individually prescribed according to general principles of cardiac rehabilitation. Importantly, the target training heart rate must remain at least 20 beats per minute below the programmed ventricular tachycardia (VT) detection threshold that triggers ICD therapy.

$\text{Target HR} < (\text{VT}_{\text{threshold}} - 20\ \text{bpm})$

Contraindications to exercise training in ICD patients include: standard contraindications to cardiac rehabilitation, the first 6 weeks after ICD implantation (due to risk of lead dislodgement), unstable or not yet optimized antiarrhythmic pharmacotherapy, planned catheter ablation of arrhythmia substrate, and an increase in ICD shock frequency (which requires immediate consultation with the implanting or follow-up center).

Because of the moderate to high potential risk of complications, exercise sessions in ICD patients should be medically supervised, with continuous ECG and blood pressure monitoring. Training facilities must be equipped with full resuscitation equipment and a magnet to temporarily deactivate the ICD in case of inappropriate shocks. Supervising staff should also have direct access to the ICD implantation or follow-up center. The clinical outcomes and safety profiles of exercise interventions vary significantly depending on the underlying cardiac pathology. A systematic synthesis of these findings, including specific heart rate (HR) safety margins and recommended modalities for Heart Failure, ARVC, LQTS, HCM, and Brugada Syndrome, is presented in Table 1.

Table 1. Clinical guidelines for exercise prescription and safety monitoring in ICD recipients by underlying pathology

Cardiac Condition	**Recommended Exercise Modality & Intensity**	**Clinical Considerations & Pathophysiological Risks**	**Safety Parameters & Heart Rate (HR) Targets**
Heart Failure (HFrEF/HFpEF)	Moderate-intensity continuous aerobic training; combined aerobic-resistance protocols [14, 48]. HIIT for clinically stable patients [49].	Improvement in VO_2peak and health-related QoL. Mitigation of heart failure-related hospitalizations [14, 44].	Target HR < (VT detection zone - 20 bpm) [49].
Arrhythmogenic Right Ventricular Cardiomyopathy (ARVC)	Low-to-moderate intensity; strict avoidance of high-intensity/competitive sports [22].	Mechanical wall stress leads to desmosomal detachment and fibrofatty replacement [37].	Individualized risk stratification; monitoring for exercise-induced remodeling [22, 37].
Long QT Syndrome (LQTS)	High-intensity activity permissible only under expert clinical supervision and optimized therapy [47].	Metabolic acidosis and electrolyte shifts may lower the VF threshold during peak exertion [20, 47].	Mandatory beta-blocker compliance and continuous clinical oversight [47].
Hypertrophic Cardiomyopathy (HCM)	Structured, supervised aerobic training in a controlled clinical environment [41].	Utilization of 3D speckle tracking to identify strain patterns associated with SCD risk [36].	Prioritization of "ATP-centric" programming to minimize shock-related psychological trauma [41].

Brugada Syndrome	Moderate-intensity exercise; avoidance of hyperthermia-inducing exertion [40].	Sympathoadrenal surge may shorten cardiomyocyte refractory periods, facilitating EADs [40].	Continuous monitoring of autonomic modulation and Heart Rate Variability (HRV) [42, 46].

Footnotes and Abbreviations:
ATP: Antitachycardia Pacing; **bpm**: beats per minute; **EADs**: Early Afterdepolarizations; **HIIT**: High-Intensity Interval Training; **HR**: Heart Rate; **HRV**: Heart Rate Variability; **QoL**: Quality of Life; **SCD**: Sudden Cardiac Death; **VF**: Ventricular Fibrillation; **VT**: Ventricular Tachycardia.

DISCUSSION

The present review synthesizes a growing body of evidence confirming that physical activity (PA) and structured exercise training are not only safe but constitute a pivotal therapeutic adjunct in the management of patients with implantable cardioverter-defibrillators (ICDs). The transition from traditional sedentary recommendations to active rehabilitation reflects a paradigm shift in electrophysiology, supported by robust data from randomized controlled trials (RCTs) and long-term observational cohorts. Interestingly, device-derived data can also capture the impact of lifestyle changes on cardiac health. For instance, Olsson et al. [46] observed that national holidays are often associated with reduced physical activity and increased fluid accumulation in ICD patients. This underscores the potential of CIED sensors to serve as early warning systems for heart failure decompensation triggered by behavioral shifts, allowing for timely intervention before clinical symptoms worsen. From a healthcare quality management perspective, implementing standardized physical activity protocols for ICD patients minimizes the risk of service failure (e.g., inappropriate shocks) and enhances the overall efficiency of cardiac rehabilitation programs. Ensuring safety through the 20 bpm safety margin (Table 1) is a critical quality indicator in modern sports medicine.

PA as a Surrogate of Autonomic Stability and Prognosis

The utility of device-measured PA extends beyond mere functional assessment; it serves as a continuous, objective biomarker of cardiovascular homeostasis. Our analysis highlights a significant correlation between high PA levels and enhanced cardiac autonomic modulation, evidenced by increased heart rate variability (HRV) [11, 12]. From a mechanistic standpoint, this shift toward parasympathetic dominance may elevate the ventricular fibrillation threshold, thereby providing a physiological buffer against arrhythmogenesis.

The prognostic weight of PA is underscored by the observation that early post-implantation activity levels inversely correlate with all-cause and cardiac mortality [15, 27]. Crucially, the data suggest that a decline in PA is not merely a passive reflection of advancing heart failure (frailty), but a modifiable risk factor. The independent association between time-varying PA and survival, absent an increase in ventricular arrhythmias (VAs), suggests that "prescribing" activity may directly influence the clinical trajectory of CIED (Cardiovascular Implantable Electronic Device) recipients.

Safety Profile of Aerobic and High-Intensity Training

A primary concern in ICD therapy remains the risk of exercise-induced VAs or inappropriate shocks due to sinus tachycardia. However, the evidence from Dougherty et al. and subsequent meta-analyses [5, 6, 8, 10, 29, 28] provides comprehensive empirical evidence against these concerns. The stability of arrhythmic profiles across various exercise intensities suggests that the myocardial substrate in most ICD recipients is remarkably resilient to the sympathoadrenal surge associated with moderate-to-strenuous exertion.

The emergence of High-Intensity Interval Training (HIIT) as a viable modality represents a significant frontier. While traditional moderate-intensity continuous training (MICT) is well-established, HIIT's superior ability to improve VO2peak—a gold-standard surrogate for survival—without a concomitant rise in tachyarrhythmia burden suggests it may be the preferred modality for optimizing cardiorespiratory fitness in selected, stable patients. The occurrence of isolated appropriate shocks during HIIT should be viewed not as a contraindication, but as a prompt for precise programmed detection zones and individualized heart rate monitoring.

Integrative and Remote Rehabilitation Models

The shift toward multidimensional programs (aerobic, resistance, and flexibility) and Home-Based Cardiac Rehabilitation (HBCR) addresses the contemporary need for personalized medicine. The success of HBCR in improving patient self-efficacy [30] is particularly relevant in the post-pandemic era. The COVID-19 lockdowns served as a "natural experiment" demonstrating the deleterious effects of physical deconditioning, where a 15% reduction in PA was directly linked to increased hospitalization and shock frequency [31, 32]. As noted by Ontario Health [35] and Westphal et al. [42], remote monitoring (RM) provides an essential safety net for patients exercising outside of clinical settings, enabling early detection of asymptomatic arrhythmias. Furthermore, the integration of structured combined training programs—incorporating aerobic, strength, and flexibility exercises—has proven both safe and efficacious in improving overall cardiorespiratory fitness [41] These findings mandate the integration of telemonitoring and remote activity coaching into standard post-implantation care.

Psychosocial Synergies and Clinical Stratification

The interplay between psychological distress and physical capacity remains a critical, yet underaddressed, domain. The association between depressive symptoms and reduced 6-minute walk test performance [3] suggests a bidirectional relationship where mental health directly impacts functional recovery. Furthermore, the use of Cardiopulmonary Exercise Testing (CPET) parameters, such as the VE/VCO2 slope and VO2 peak, allows for a refined risk stratification that distinguishes between purely mechanical/hemodynamic failure and arrhythmic vulnerability [19, 33].

CONCLUSIONS

1. Increased physical activity after ICD or CRT-D implantation is associated with reduced cardiac and all-cause mortality.

2. Moderate-intensity aerobic exercise is safe and does not increase ventricular arrhythmias or ICD therapies.
3. Supervised high-intensity interval training appears safe in carefully selected patients and improves VO_2peak and quality of life.
4. Combined and home-based cardiac rehabilitation programs are feasible and enhance functional and psychological outcomes.
5. Device-derived physical activity monitoring provides meaningful prognostic information and may serve as both a risk marker and therapeutic target.
6. Exercise capacity parameters (e.g., VO_2peak, VE/VCO_2 slope) contribute to risk stratification but do not directly predict ICD shocks.
7. Maintenance of physical activity should be prioritized in ICD patients, even during external stressors such as public health emergencies.

Overall, current evidence supports structured physical training as a safe and beneficial component of comprehensive care in ICD recipients, provided that individualized risk assessment and appropriate supervision are ensured.

Disclosures:

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Validation: AS, JŁ, KF

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