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Sports Cardiology (M Wasfy, Section Editor)

# Sport Participation in Patients with Implantable Cardioverter-Defibrillators

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## Abstract

*Purpose of review* Athletes diagnosed with cardiovascular disease may receive implantable cardioverter defibrillators (ICDs). Until recently, there were no data describing the safety of return to play for athletes receiving an ICD, and consensus recommendations restricted ICD patients to competitive sports no more vigorous than bowling or golf.
*Recent findings* The ICD Sports Registry prospectively followed 440 athletes who continued sports participation after receiving an ICD, for up to 4 years. While many received shocks, both appropriate and inappropriate, during competition or practice, as well as during other physical activity or rest, there were no failures to defibrillate and no injuries related to arrhythmia or shock during sports. Recent subanalyses as described below have focused on how best to program the ICD, and on the younger subgroup including interscholastic athletes.
*Summary* Based on these data, the most recent consensus statement from the AHA/ACC on athletic eligibility now describes sports participation with an ICD as a IIB recommendation, "may be considered".

## Introduction

How many athletes receive implantable cardioverter-defibrillators (ICDs) is unknown. Athletes can present with symptoms such as syncope [1] or cardiac arrest, [2] leading to a diagnosis of cardiovascular disease, or can be diagnosed through screening efforts, either specific pre-participation evaluation (PPE) or routine family screening. After the diagnosis, ICD may be recommended, either for secondary prevention following a life-threatening ventricular arrhythmia or for primary prevention following standard disease-specific risk

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assessment for risk of sudden cardiac death. How best to screen for cardiovascular disease in the athlete remains controversial. In Europe, inclusion of an ECG with the standard history and physical is recommended by professional societies [3]. In the USA, consensus statements continue to support PPE with just history and physical exam [4], but many universities in the USA have added ECG to the PPE [5, 6]. H&P alone can also diagnose cardiac disease. Other athletes may be diagnosed following the diagnosis of a symptomatic family member, through standard-of-care family cascade screening [7, 8]. Many of these symptomatic and asymptomatic athletes will receive defibrillators, raising the question of the safety of return to play.

### Historical perspective

While this question was controversial for many years [9], until recently, both US and European consensus statements [10–12] restricted patients with ICDs to participation in sports no more vigorous than the "IA", low-dynamic/low-static activities such as bowling or golf. In what was, for many years, the absence of data, experts based their recommendations on hypothesized concerns including, first, whether the device would successfully defibrillate an arrhythmia, given the autonomic and metabolic milieu of competitive sports [13, 14], next, injury due to loss of control due to arrhythmia-related syncope and/or shock, and finally, damage to the ICD system. However, restriction from sports can significantly decrease quality of life, as shown in a study of sidelined athletes [15] as well as patients with ICDs. For many adolescents with ICDs, restriction from sports was the biggest factor impacting their quality of life [16].

In order to collect data to better guide recommendations, in 2006, our group carried out a retrospective survey of Heart Rhythm Society physician-members [17], of whom 40% responded. Their answers to this survey suggested that first, physician recommendations varied widely, from those who counseled athletes based strictly on the current published recommendations, to those who counseled no restriction at all. Further, this survey revealed that many ICD patients were participating in sports, despite the consensus recommendations. Finally, no adverse events related to participating in sports with an ICD were reported. While survey results are limited by selection and recall bias, these results suggested that a prospective registry of athletes with ICDs was feasible, ethical, and necessary. Feasible, as many ICD patients were participating in sports. Ethical, as study participants were already playing and were not asked to do activities whose safety was unknown. Necessary, as if the risks were as great as hypothesized, those participating needed to know, while if not, others might choose to participate.

## The ICD Sports Registry

Based on the preliminary results provided by this survey, the ICD Sports Safety Registry, a multinational, prospective, observational registry, was established to identify and quantify risks associated with sports participation for ICD patients. In this study, whose 2-year results were published in 2013 and 4-year results in 2017 [18, 19••], 440 athletes with ICDs, age 10–60, 2/3 male, 46% with a history of ventricular arrhythmia (secondary prevention), who had chosen to continue to compete in sports with greater than "IA" in static/dynamic intensity, were followed prospectively. Participants were contacted regularly in follow-up, and ICD records obtained and rhythms adjudicated for shocks received at any time. Most common cardiac diagnoses were LQTS, HCM, and CAD, and most common sports, running, soccer, and basketball.

Over a median follow-up of 44 months, there were no occurrences of the primary endpoints—no failures of the ICD to defibrillate or externally resuscitated arrest, and no injuries due to syncopal arrhythmia or loss of control following shock. The 95% confidence interval for the occurrence of adverse event based on 376 participants followed up at least 2 years was 0% to 0.9% and based on 167 participants followed up at least 4 years was 0% to 2.2%.

Many participants received shocks, as shown in Table 1. Forty-six (10%) received appropriate shocks (for VT/VF) during competition or practice, a rate of 3 per 100 person-years, with all ventricular arrhythmias appropriately terminated by the device. While more received shocks during some form of physical activity than during rest, there was no difference between competition/practice and other physical activity [19••]. Rates of lead malfunction were similar to those reported in unselected populations [20].

The impact of shocks on quality of life was not measured in the ICD Sports Registry. ICD shocks decrease quality of life, shown in many studies [21]. However, while about one-third of those athletes who received

**Table 1. Numbers of shock-events and of individuals receiving shocks (reprinted with permission from Lampert, Circulation 2017 [19])**

| Rhythm | Competition-related | Physical activity-related | Rest | Total, *n* (%) |
|---|---|---|---|---|
| Total cohort *N* = 440 | | | | |
| VT | 29/21 | 15/11 | 19/13 | 63/41 (9) |
| VF | 12/10 | 9/8 | 14/9 | 35/25 (6) |
| VT/VF storm | 4/4 | 3/3 | 2/2 | 9/9 (2) |
| NSVT | 1/1 | 0 | 0 | 1/1 (1) |
| SR | 8/7 | 4/3 | 1/1 | 13/10 (2) |
| AF | 7/5 | 14/10 | 4/4 | 25/14 (3) |
| Other SVT | 3/3 | 4/4 | 1/1 | 8/8 (2) |
| SR storm | 0 | 1/1 | 0 | 1/1 (1) |
| AF/SVT storm | 0 | 2/2 | 0 | 2/2 (1) |
| T wave oversensing | 2/2 | 3/2 | 3/3 | 8/7 (2) |
| Noise | 1/1 | 7/7 | 11/10 | 19/17 (4) |
| Total | 67/51 | 62/46 | 55/42 | 184/121 (28) |
| Highly competitive subgroup *N* = 77 | | | | |
| VT | 1/1 | 5/5 | 2/2 | 8/3 (3) |
| VF | 4/3 | 3/1 | 5/2 | 12/4 (4) |
| VT/VF storm | 1/1 | 0 | 0 | 1/1 (1) |
| AF | 1/1 | 2/1 | 0 | 3/2 (2) |
| Other SVT | 0/0 | 2/2 | 2/2 | 4/4 (5) |
| AF/SVT storm | 0/0 | 1/1 | 0/0 | 1/1 (1) |
| T wave oversensing | 1/1 | 2/1 | 2/2 | 5/4 (5) |
| Noise | 1/1 | 1/1 | 1/1 | 3/3 (3) |
| Total | 9/8 | 16/13 | 12/8 | 37/25 |

Values refer to number of events/number of unique individuals. %s refer to % of study population
*VT* ventricular tachycardia, *VF* ventricular fibrillation, *NS* non-sustained, *SR* sinus rhythm, *AF* atrial fibrillation
Includes competition, post-competition, or practice for competition; includes physical activity and post-physical activity
Among the total cohort, 33 shocks did not have available ICD-stored data, diagnosis is based on that of the treating physician. Of these, 13 were ventricular arrhythmia, 4 supraventricular, 13 noise, 3 other. Among the highly-competitive subgroup, six shocks did not have available ICD-stored data, 3 noise, 1 VF, 1 T-wave oversensing, and one other SVT

shocks during sports stopped playing one or all sports for a period of time, most returned to play later on, suggesting that the beneficial impacts of sports participation on quality of life outweighed the negative impact of shocks for most athletes.

# Change in consensus recommendations

Based on these data from the ICD Sports Registry, in the updated "Eligibility and Disqualification Recommendations for Competitive Athletes With Cardiovascular Abnormalities: Task Force 9: Arrhythmias and Conduction Defects: A Scientific Statement From the American Heart Association and American College of Cardiology" [22••], competitive sports participation for patients with an ICD no longer carries a blanket restriction, but rather, a "IIB" recommendation, "may be considered".

# Recent developments

## In-depth reports of subgroups from the ICD Sports Registry

While there were no adverse events in the group as a whole, and thus, no adverse events in any subgroups, more detailed descriptions of the populations enrolled will help guide individualized decision-making for the athlete considering return to play after an ICD (as described in more detail below in the "shared decision making" section). The first subanalysis of the ICD Sports Registry described the younger population, 179 total who were 21 years of age or younger [23•], which included the most competitive individuals—79 athletes completing at interscholastic varsity levels (Fig. 1). Twenty athletes were participating at the university interscholastic level. Diagnoses were similar to the overall population, and varsity sports included soccer, basketball, lacrosse, and others [23•]. Overall, there were six appropriate shocks in four individuals during competition or practice, a rate of 1.5 appropriate shocks per hundred person-years. These data further emphasize that the decision to return to play should be individualized, even for the young, highly-competitive varsity athlete.

Further subanalyses of the disease entity-subgroups making up the ICD Sports Registry are in progress, with a report on the HCM patients expected soon, and those on ARVC and LQTS subpopulations to follow.

## ICD programming in the athlete

Another recent subanalysis [24•] has focused on appropriate programming to minimize the likelihood of inappropriate shocks in this population. In the ICD Sports Study, those athletes whose ICDs were programmed with higher rate-cut-offs for the first therapy zone (greater than 200 bpm) and those programmed with detection-duration greater than the nominal settings were less likely to receive inappropriate shocks, and those with both these settings, the least likely. Programming was not prescribed in this study, but findings were similar to large randomized controlled studies in the general ICD population [25]. There was no increase in syncope prior to shock in those athletes with higher rate-cut-off/ longer duration. While two athletes had ventricular tachycardia that was below the rate cut-off and thus was not treated, the arrhythmias were minimally

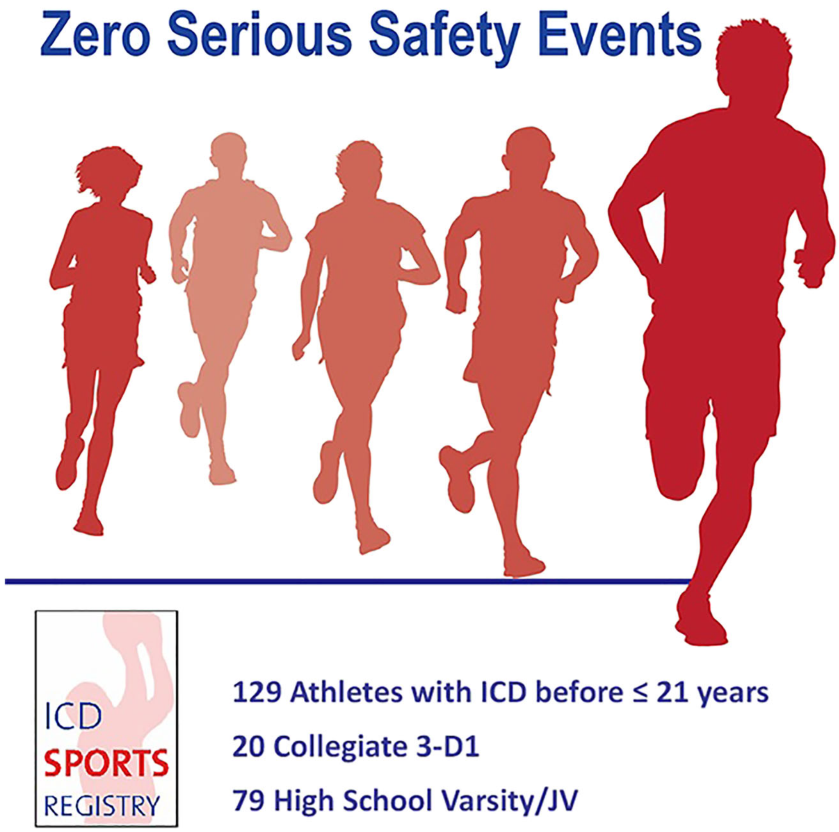


**Fig. 1.** Zero serious safety event (reprinted with permission from Saarel, Circulation Arrhythmias and Electrophysiology, 2018 [23])

symptomatic, presenting as palpitations. There was no difference in shock rates based on dual- versus single-chamber device, or number of therapy zones.

# Unanswered questions

## Does sports participation increase the risk of arrhythmia?

While the ICD Registry demonstrated that it is safe for many athletes with ICDs to continue to compete, whether participation in competitive sports increases the risk of ventricular arrhythmias requiring shock for termination is not yet determined, as only those actively competing were enrolled. Two series suggest that the risk of sudden cardiac death (SCD) is higher in athletes than nonathletes. A landmark study from Italy [26], in which all athletes and all deaths are entered in centralized databases, found that, prior to initiation of ECG screening, SCD was more frequent in athletes. Also, in a prospective observational study of US high schools, SCD was more frequent in athletes than non-athletes [27]. However, these were individuals with previously undiagnosed disease. Whether competitive sports participation increases likelihood of arrhythmia in patients who are appropriately treated and risk-assessed has not been determined. Small retrospective series of LQTS [28, 29] and HCM [30] have not shown worse outcomes in athletes who continue sports participation versus the sedentary.

A subanalysis of the ICD registry compared the primary population with a subpopulation of intensive recreational athletes enrolled in Europe [31•] (and not described in the papers focused on competitive athletes) and found that arrhythmias with physical activity were more common in those competing than those practicing sports recreationally. However, there were differences between the European and US athletes. In the general population, the "paradox of exercise" is well-described [32]. While overall, sudden death is less common in those who exercise vigorously, the risk of an event is higher during exercise. While often considered a "paradox", this is likely explained by the role of the autonomic nervous system in arrhythmogenesis. Catecholamines are known to promote arrhythmias [33]. For the well-conditioned, catecholamines will be highest when they are vigorously exercising. Whether a similar "paradox of exercise" exists in the genetic cardiovascular diseases most common in the athlete-ICD population is unknown. An ongoing observational study, Exercise in Genetic Cardiovascular Disease (NIH # R01 HL125918-01), now in the follow-up phase, has enrolled individuals with HCM and LQTS (in two parallel studies, Lifestyle and Exercise in HCM (LIVE-HCM) and Lifestyle and Exercise in LQTS (LIVE-LQTS) at all levels of exercise, both with and without ICDs, to determine whether arrhythmic endpoints are more or less frequent in patients who exercise compared to those who do not (http://www.livehcm.org/ and http://livelqts.org/).

## How does sports participation impact the underlying disease process?

The ICD Sports Registry did not evaluate if or to what degree vigorous exercise may exacerbate the progression of cardiomyopathies. For some of these entities, namely arrhythmogenic right ventricular cardiomyopathy (ARVC), increasing data suggest that vigorous exercise may accelerate the progression of the phenotype. For others, such as hypertrophic cardiomyopathy and dilated cardiomyopathy, data are lacking. For patients with ARVC, there are increasing data in both animals [34, 35] and patients [36, 37] that high-level exercise may accelerate progression of the cardiomyopathy in this disorder. For ARVC patients in the ICD Sports Registry, while the ICD was always successful at converting ventricular arrhythmias, these were the patients most likely to experience both single and storms of ventricular arrhythmias during sports. For patients with ARVC, the disease process, rather than the ICD per se, should guide the risk evaluation of sports participation.

How exercise may impact the myopathic process in HCM is not yet known. In a murine model of HCM, exercise was actually beneficial. In animals who had not yet developed the HCM phenotype, exercise prevented fibrosis and myocyte disarray, and in animals who had already developed HCM, exercise led to regression of disarray, and to improvements in components of the apoptotic signaling pathway [38]. In a recent study of controlled increases in moderate exercise in sedentary HCM patients [39], physical conditioning improved, there were no arrhythmias, and no changes in echo parameters, although this was a short intervention, and did not include maximal vigorous exercise.

## Safety in CPVT

Catechominergic polymorphic VT (CPVT) is unique in that an ICD is not nearly as successful at converting an arrhythmia as it is in other arrhythmogenic conditions [40]. ICD shocks increase catecholamines, even in a sedated patient [33] and this can create a vicious cycle of arrhythmia recurrence for a patient with CPVT. One small series has described appropriately treated CPVT patients, mostly without ICDs, participating in sports [41]. In one series of 15 CPVT patients with ICDs, 6 were treated for ventricular arrhythmias. Two died of VT refractory to ICD treatment, including one whose VT was triggered by an inappropriate shock for AF [40]. In the ICD Sports Registry, another subset of patients with ventricular arrhythmias requiring multiple shocks for termination were those with "idiopathic VF". As CPVT is electrically silent at rest, it is highly possible that some "idiopathic VF" may represent undiagnosed CPVT. Treadmill testing is imperative to evaluate for CPVT, and genetic testing should be considered.

## What type of ICD should be implanted?

In the ICD Sports Registry, all athletes had transvenous (or a few, epicardial) lead systems. However, data demonstrating the safety and efficacy of the totally subcutaneous ICD (S-ICD), approved by the FDA in 2012 for the general population of ICD patients, are continuing to increase [42, 43] and efficacy at conversion of ventricular arrhythmia is similar to that of transvenous devices [44]. In general, the implant complications, while similar in number to that for the transvenous device, carry lower morbidity (i.e., no risk for pneumothorax or perforation.) Prevention of inappropriate shock is also critical for the athlete, in whom sinus rates may be above standard rate cut-offs. The S-ICD uses correlation waveform analysis to discriminate atrial from ventricular arrhythmias. In experimental studies, discrimination was excellent, 98%, better than most of the TV systems tested [45], and clinically, inappropriate shock rates have been similar to the TV system in unselected populations [25, 42].

Given these data showing similar efficacy and safety, what device is best suited for an athlete? The main criteria driving choice may be likelihood of injury to the lead or generator from the specific sport. Lead malfunction is the major bane of the ICD. A transvenous lead traverses the venous system and is subject to hundreds of millions of cardiac cycles. Lead survival free of malfunction in unselected populations has varied from 85 to 98% at 5 years in multiple studies [20]. In the ICD Sports Safety Registry, lead survival free of definite or probable malfunction was 93% at 5 years. Whether some sports, however, may increase the likelihood of lead damage is unknown. One well-recognized mechanism of lead damage is entrapment of the lead as it passes between the clavicle and first rib, where the lead can become compressed, termed the "subclavian crush syndrome" [46]. It has been hypothesized that sports with intensive involvement of the arms, such as swimming or rowing, may increase likelihood of subclavian crush. Analysis of lead function by sport in the ICD Sports Registry is ongoing. It is too soon to confirm the long-term lead survival of the S-ICD. However, for an athlete wishing to participate in these types of sports, avoidance of subclavian crush may favor the S-ICD.

For contact sports, on the other hand, the position of the generator may drive the decision. For the transvenous device, the generator is placed pre-pectorally, protected by standard padding for contact sports such as American football or ice-hockey, while the S-ICD generator is placed lower and laterally, over the lower ribs, and may be less protected. What device is best-suited to the athlete remains an important avenue of future research.

## The role of shared decision-making in the return to play decision for an athlete with an ICD

How shared decision-making should fit into return to play decisions is a controversial area. While many feel that shared decision-making has as much role in a return to play decision for an athlete with an ICD (or other cardiovascular disease) as for any other medical decision [47••, 48–50], others take the more paternalistically driven traditional approach [51] that consensus statements should provide unambiguous yes-or-no guidance. Shared decision-making, termed the "pinnacle of patient-centered care" [52], requires the physician to explain the risks and benefits of options and to help patients understand how to reconcile these options with their personal preferences and values. This means full discussion with the patient, and often family—What are the risks? What data do we have, and how does this patient compare to the patients in the studies? For example, for an ice-hockey player, it is important to explain that there were very few patients in the study engaged in sports in which violent contact is an intrinsic and purposeful part of the game, and it is possible that system damage may be greater than what was seen in the ICD Sports Registry. What data are lacking? For example, as above, while we know that shocks occur during sports, whether shocks would be less likely with discontinuing sports is unknown. Further, while there were no adverse events in the 440 patients in the ICD Sports Registry over 4 years, this study is not large enough to say risk is zero. What do the professional society guidelines recommend? How does this patient and family think about risk in general? Different families have very different tolerance for risk. For example, some families climb Mt. Everest with their teenagers, while others do not allow tackle football. This shared decision-making approach requires a combination of knowledge of the data, and willingness to engage the patient (and often family) as partners in the decision-making process. Most importantly, we need to stress that we do not have all the answers, while providing a framework for decision-making.

## Compliance with Ethical Standards

**Conflict of Interest**
Rachel Lampert reports grants from Medtronic, St Jude/Abbott, and Boston Scientific.

**Human and Animal Rights and Informed Consent**
This article does not contain any studies with human or animal subjects performed by any of the authors.

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