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Athletes with Implantable Cardioverter Defibrillators

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Summary

Athletes with an implantable cardioverter defibrillator (ICD) represent a diverse group of individuals who may be at an increased risk of sudden cardiac death (SCD) when engaging in vigorous physical activity. Therefore, they are excluded by the current guidelines from participating in most competitive sports except those classified as low intensity, such as bowling and golf. The lack of substantial data on the natural history of the cardiac diseases affecting these athletes, as well as the unknown efficacy of implanted ICDs in terminating life-threatening arrhythmias occurring during intense exercise, have resulted in the restrictive nature of these now decade old guidelines. Recently, there is emerging data, derived from a few retrospective studies and a large prospective registry that demonstrates the relative safety of high-risk athletes participating in competitive sports and challenges the prohibitive nature of these guidelines. Nevertheless, the safe participation of all athletes with an ICD in competitive sports continues to be contemplated. The increased number of inappropriate shocks, damage to the ICD/pacemaker system, and the questionable efficacy of the delivered shock in the setting of vigorous physical activity are some of the main challenges faced by these athletes who choose to continue participation in competitive sports. The fear of SCD and ICD shocks faced by these athletes is also

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associated with a negative psychological burden and affects their quality of life, as does restricting them from all competitive sports. Therefore, shared decision making is necessary between the clinician and athlete after carefully analyzing the risks and benefits associated with competitive sports participation.

Keywords

Arrhythmia; Athlete; Bethesda Conference; Brugada Syndrome; Exercise; Implanted cardioverter-defibrillator (ICD); Long QT syndrome; Sudden Cardiac Death; European Society of Cardiology (ESC)

Introduction

The use of implantable cardioverter-defibrillators (ICDs) for primary and secondary prevention of sudden cardiac death (SCD) has increased in the last two decades due to their proven efficacy in treating life-threatening cardiac arrhythmias. [1–3] The indications for implantation of ICDs in athletes are the same for those in the general population. [2, 4] The athletic heart is faced with a milieu of increased emotional stress, hemodynamic changes, altered autonomic tone, and the potential for myocardial ischemia that can occur during vigorous physical exertion. Especially in athletes with a substrate of underlying cardiovascular disease, these factors may acutely and transiently increase the risk for SCD through initiation and perpetuation of life-threatening dysrhythmias.[5–8]. These factors along with mandatory pre-participation screening recommended by the American Heart Association (AHA)[9] and the European Society of Cardiology (ESC) [10] for participation in most competitive sports have led to an increased recognition of athletes at risk for SCD [11], and thus the issue of ICD implantation has come to the forefront. ICD therapy could be considered in athletes who are at increased risk of developing malignant arrhythmias, such as those with underlying electrical or structural cardiac abnormalities associated with hypertrophic cardiomyopathy (HCM), long QT syndrome (LQTS), Brugada syndrome (BrS), or arrhythmogenic right ventricular cardiomyopathy (ARVC).[12]

Current international guidelines [4, 9, 13, 14] recommend only moderate, leisure-time physical activity in patients with an ICD, thus making athletes with ICDs ineligible for most competitive sports except those classified in North America as so-called **class IA** sports (billiards, bowling, cricket, curling, golf, and riflery) (Figure 1).[15] Despite these very restrictive guidelines, many athletes with ICDs and normal left ventricular function have a strong passion to continue their participation in organized, and often high intensity sports, thereby posing a medical and ethical dilemma for the treating physician.[12]. In this review, we summarize the current recommendations for athletes with ICDs, the major controversies that exist, the risks associated with ICDs, and the importance of shared-decision making between clinician and athlete.

Section I. Examination of guideline-based recommendations for athletes and arrhythmias

The two most widely accepted guidelines used for determining the eligibility to participate in competitive sports are from 1) the United States- 36th Bethesda conference (BC #36), and 2) Europe- the ESC expert consensus document.[4, 16, 17] These documents were published in 2005, and contain recommendations made based on the available scientific data, as well as individual and collective judgment and experience of the panel participants. Although these documents largely agree on their recommendations about athletic participation in patients with underlying cardiac disease, the discrepancies in their approach to disqualification of athletes may be reflective of the very different cultural, social, and legal backgrounds existing in the U.S. and Europe.[18] These conflicting recommendations can be confusing to clinicians caring for athletes. Therefore, we present the commonly agreed upon points from each of the guidelines, as well as highlight the major disease-specific discrepancies from both expert panels (Table 1).

Section IA. Overall general recommendations endorsed by both the BC #36[4, 16] and the ESC [17]

1. Athletes with syncope or near syncope should not participate in sports where the likelihood of even a momentary loss of consciousness may be hazardous until the cause has been determined and treated, if necessary.
2. Any athlete with a previously diagnosed arrhythmia should be re-evaluated every 6–12 months during training to determine if the conditioning process has affected the underlying arrhythmia.
3. Athletes on any anti-arrhythmic drug therapy to control their arrhythmia should be periodically checked for compliance with recommended therapy and for any recurrence of symptoms.
4. Abuse with drugs such as cocaine and ephedra may induce life-threatening arrhythmias and may need to be considered during evaluation of these athletes.
5. For some arrhythmias in athletes, an ablation approach may be preferred to drug treatment as catecholamines released during exercise may undermine the salutary effects of some antiarrhythmic agents. After such a successful ablation, return to athletics may be as quick as within few days if repeated attempts at tachycardia induction during isoproterenol administration were unsuccessful. If no such testing was done, then a 2–4 weeks interval is recommended.
6. For athletes with ICDs, all moderate and high intensity sports are contraindicated and only **class IA** sports[15] are permitted as the efficacy with which these devices will terminate a potentially lethal arrhythmia under the extreme conditions of competitive sports, with the associated metabolic and autonomic changes, and possible myocardial ischemia, is unknown.
7. Athletes who require anticoagulation should not participate in sports with a danger of bodily collision.

8. Athletes with ICDs/pacemakers should not engage in competitive sports with a danger of bodily collision/physical contact because such trauma may damage the ICD/pacemaker system.

*It should be noted that the use of certain cardioactive drugs, such as beta-adrenergic blocking agents, is banned in some competitive sports.

Section IB. Arrhythmia specific recommendations

The most important prognostic determinant of the arrhythmogenic potential in an athlete is the presence of underlying heart disease.[17, 19–22] Specific recommendations points from the consensus documents (BH #36 and ESC) pertaining to major cardiac conditions is presented below:

1) Hypertrophic cardiomyopathy (HCM)

Task force 4 (BC #36)[23]

1. Individuals with a positive genetic test but no clinical evidence of the disease (genotype positive and phenotype negative) are not precluded from participation in competitive sports.
2. All other individuals irrespective of age, gender, phenotype or symptoms, with probable or equivocal clinical diagnosis of HCM can only participate in low intensity (**class IA**) sports.

ESC

1. ESC recommendations are more restrictive in patients with HCM and recommend only leisure time or non-competitive sporting activities even in individuals with solely a positive genetic test.
2. Athletes with clinical or phenotypic evidence of HCM are restricted from ALL competitive sports, even the BC-sanctioned safe sports (**class IA**).

These recommendations by the ESC guidelines are based on the fact that there is lack of sufficient data on the natural history of HCM in competitive athletes and the hypothesis that intense training and competitive sports can lead to activation of cellular pathways causing expression of the HCM phenotype (i.e., left ventricular hypertrophy) and thereby lead to an increased risk of tachyarrhythmias and SCD in athletes with a predisposing gene abnormality.[24–26]

2) Arrhythmogenic right ventricular cardiomyopathy (ARVC)

Task force 4 (BC #36)[23]

- Athletes with probable or definite diagnosis of ARVC should be excluded from most competitive sports, with the possible exception of those of low intensity (**class IA**).

ESC

- Athletes with ARVC should be excluded from all competitive sports including low intensity (**class IA**).

3) Ventricular flutter and ventricular fibrillation in athletes with ICDs**Common endorsements by both ESC and Task Force 7 (BC #36)[4]**

1. Athletes with conditions that result in cardiac arrest in the presence or absence of structural heart disease generally are treated with an ICD and cannot participate in any moderate- or high-intensity competitive sports or those that involve bodily contact.
2. Athletes with ICDs and who have had no episodes of ventricular flutter or ventricular fibrillation, but require device therapy may need to wait six months before engaging in **class IA** competitive sports.

4) Cardiac Channelopathies**A. Long QT Syndrome (LQTS)****Task force 7 (BC #36)[4]**

1. In athletes who are symptomatic (cardiac arrest or syncopal episode(s)), all competitive sports, except those in the **class IA** category, should be restricted irrespective of their QTc or underlying genotype.
2. Asymptomatic patients with a baseline QT prolongation (QTc of 470 ms or more in males, 480 ms or more in females) should be restricted to **class IA** sports.
3. Asymptomatic patients with genetically proven type 3 LQTS (LQT3) that are currently restricted to **class IA** sports, may be considered for more liberalization.
4. Asymptomatic athletes with genotype-positive/phenotype-negative LQTS may be allowed to participate in competitive sports.
5. Due to the strong association between swimming and LQT1, athletes with genotype-positive/phenotype-negative LQT1 should refrain from competitive swimming.

ESC

1. All patients with a confirmed diagnosis of congenital LQTS should be excluded from all competitive sports including those in **class IA**, irrespective of their genotype and symptoms.
2. Athletes with solely a positive genetic test should be excluded from all competitive sports.

5) Short QT Syndrome (SQTS)

Task force 7 (BC #36)[4]

- In all athletes with SQTS, participation in all competitive sports except those in **class IA** should be restricted.[27]

6) Catecholaminergic Polymorphic Ventricular Tachycardia (CPVT)

Task force 7 (BC #36)[4]

1. Symptomatic patients without ICD [28] are restricted to only **class IA** sports.
2. Asymptomatic patients detected as part of familial screening with documented exercise- or isoproterenol-induced VT should refrain from all competitive sports except possibly **class IA** activities.
3. In asymptomatic athletes with no inducible VT (genotype-positive and phenotype-negative), restrictions for competitive sports may be more relaxed.
4. As with LQT1, all patients with CPVT should be restricted from competitive swimming.

7) Brugada Syndrome (BrS)

Task force 7 (BC #36)[4]

- No clear association between exercise and SCD in patients with BrS has been thus far established, but due to the potential impact of hyperthermia in these patients, they are advised to refrain from all competitive sports except those in **class IA**.

ESC

- All patients with a confirmed diagnosis of BrS should be excluded from all competitive sports including **class IA**, irrespective of their genotype and symptoms.

Section IC. Evidence and reasons behind the recommendations for athletic restriction

The current recommendations by the ESC and BC #36 consensus documents restrict athletic participation in most competitive sports[4, 29, 30] for several reasons, these include (Table 2):

1. Intense physical exertion increases the risk of SCD by almost 2.5 times in patients with underlying arrhythmogenic cardiac disease.[11]
2. ICD efficacy in terminating a potentially lethal arrhythmia under the extreme conditions of competitive sports, with the associated metabolic [31] and autonomic changes, as well as possible myocardial ischemia[32], is unknown.[17, 33]
3. Sports with physical contact may result in damage to the ICD, thereby preventing its normal function.
4. In athletes with left hand dominance, extreme arm movements can cause ICD lead fracture due to costo-clavicular crush.[34]

5. A variety of conditions that occur during exercise like sinus tachycardia, supraventricular tachycardia with rapid conduction, T wave over sensing during exercise, or noise due to lead failure may lead to an increased frequency of inappropriate shocks in athletes with ICDs.[35]
6. The transient loss of consciousness from exercise-induced arrhythmias or inappropriate/appropriate ICD shocks may pose a serious risk of severe injury or death [36] to the athlete as well as the spectators.[37]
7. Inappropriate shocks can have a negative psychological impact [38, 39] on the athlete which in turn can lead to SCD due to facilitation and destabilization of malignant ventricular arrhythmias by altering the tachycardia cycle length.[40]
8. Inappropriate shocks can also lead to ventricular arrhythmias if delivered on the T-wave.
9. Catecholamines released during exercise may undermine the salutary effect of antiarrhythmic drugs and also exacerbate underlying conditions and may possibly lead to life threatening VT storm and repeated shocks from the device.[37, 41–43]

At the time of this book chapter's submission (March 2015), the 2005 Bethesda Conference recommendations were being re-evaluated and updated with AHA/ACC-approved guidelines. The final approval from the respective societies has not yet been obtained and an estimated publication date has not yet been provided. As such, any departures from the 2005 recommendations are unknown at this time. There has been no announcement regarding the convening of and timing for a similar update to the 2005 ESC sports participation guidelines.

In addition, subsequent disease-specific guidelines, for example, the LQTS treatment guidelines from 2013, have indicated a shift away from a presumptive disqualification to a recommendation that embraces shared-decision making between an athlete and his/her physician.[44] In essence, for an athlete with LQTS who desires to remain a competitive athlete, the internationally sanctioned guidelines now stipulate that he/she should be evaluated by an LQTS expert in order for that athlete to be well-diagnosed, risk stratified, and treated, and in that setting, then be enabled to make a well-informed decision on how he/she would like to live their life.

Section II. Challenging the current recommendations: Is it really evidence-based practice?

Section IIA. Lack of data, discrepancies in guidance, and acceptance in clinical practice

The expert committee formulating the 2005 guidelines acknowledged that these recommendations are largely based on individual and collective judgments and the experience of the panelists, and the evidence supporting them in the form of well-designed, scientifically acceptable studies were simply not present.[4, 33] The European recommendations, being more restrictive compared to the American based recommendations, allow athletes with ICDs to engage in only leisure time activities with low to moderate intensity not involving body contact or collision.[29] These types of

conflicting recommendations with respect to athletic participation in competitive sports from the above consensus statements, as well as the lack of data on the actual risk of sports in patients with ICDs, have resulted in these guidelines not being uniformly embraced by all practicing physicians.[45]

In fact, subsequent studies have documented the relative safety of athletes with ICDs participating in vigorous and competitive sports without physical injury or failure to terminate arrhythmias. These studies have also shown that ICD shock therapy during physical activity was no different during competition/exercise versus those occurring during other recreational activities.[39, 45] Furthermore, these studies have also demonstrated the relative safety of exercise training in ICD patients during cardiac rehabilitation without any increase in shocks, and also suggested an improved aerobic capacity in these patients.[46]

Section IIB. Clinician perspectives; A landmark survey of the landscape

Critical insight as to the thoughts of practicing clinicians on these guidelines was revealed by a survey involving all U.S. physician members of the Heart Rhythm Society. Clinicians were asked about their recommendations to patients with respect to ICDs and sports participation, and these data revealed a great variance from the guidelines existed. Only 10% of physicians recommended avoidance of all sports more vigorous than golf, 76% recommended avoidance of contact sports, and only 45% recommended avoidance of all competitive sports.[45] This survey also provided data about the adverse consequences of such athletic participation with 1% of physicians reporting injuries sustained by patients (all but 3 were minor); 5% were due to injury to the ICD system, and importantly, < 1% had failure of ICD shocks to successfully terminate arrhythmias. The most common adverse event reported in this survey was lead damage attributed to repetitive-motion activities, most commonly weightlifting and golf, again contradicting the current recommendations. [16, 17, 45]. In comparison, the relative risk of lead fracture reported by most other studies is about 0.4 to 4%.[47, 48]

Survey data also reported that physicians noted a high rate of ICD shocks (both appropriate and inappropriate) in patients engaging in sports with up to 52% of them reporting ICD shocks in patients participating in vigorous exercises. These findings are not surprising as the risk of SCD may increase transiently by a factor of 14 to 45 in association with an episode of vigorous exertion [7], and thereby perpetuating malignant arrhythmias in these patients.[49] It must be noted that although these shocks are associated with a negative psychological impact [46]and quality of life [50], restriction from sports participation also plays a major role in the mental well-being of these athletes. The survey also reported 2 cases of actual ICD shock failure during exercise, one of these was associated with known ethmozine-induced increase in defibrillation threshold, and the other shock failure was associated with exercise after very heavy alcohol consumption.

Section IIC. ICD Sports Safety Registry

Contrary to the theoretical concerns and expectations by some for increased risk of danger to the host and damage to the device, the results from a multi-national, prospective, observational registry of 372 athletes with ICDs participating in organized sports activities

showed no deaths or shock related injuries or generator malfunctions. In addition, the incidence of lead malfunction was not higher in athletes with ICDs compared to published rates in non-athletes.[39]

In line with the previously discussed survey based study, [45] this prospective registry-based study reported an increased rate of appropriate and inappropriate shocks that occurred during physical activity. Also, 7 out of the 8 ventricular storms recorded, occurred during exercise.[39] Although this data provides some evidence to challenge the restrictive position of the previous guidelines with respect to the athlete with an ICD, a registry-based study is limited by many factors, such as: 1) few patients had engaged in aggressive contact sports, 2) median time of enrollment was about 2 years (leading to survival or selection bias), and 3) the bias associated with the study design of self-reporting and a self-selected group. Nevertheless, it has provided an observational signal to challenge previous opinion/experience-based renderings.

Another retrospective study, involving 130 athletes with LQTS who chose to continue their participation in competitive sports, showed that 70 of the 130 athletes (54%) who were genotype positive/phenotype negative suffered no sport-related adverse events. Out of the other 60 athletes with a genotype positive/phenotype positive profile, thereby participating contrary to both guidelines, only one athlete had a sporting-related adverse event with an appropriate shock.[51, 52] The combination of these two aforementioned studies was cited by the newest LQTS-specific guidelines as the rationale for moving away from a one-size-fits-all disqualification from all competitive sports for all LQTS patients (the ESC 2005 position) to a position more consistent with the philosophy of individualized/personalized medicine and shared decision making as admonished by Johnson and Ackerman in their Mayo Clinic study.[39, 44, 51, 52]

Section IID. Individual factors: an athlete's perspective and shared clinical decision-making

When making recommendations, it is also important to take into account the individual athlete's perspective on what it would mean for them in terms of lifestyle change or quality of life when restricting them from a particular sporting activity. Physical activity and engaging in sports is known to promote psychological well being in patients with heart disease apart from its well recognized effect in reducing morbidity and mortality through various mechanisms.[53, 54] On the contrary, the increased number of shocks associated with physical activity in these patients may also have profound psychological impact, subjecting them to fear of recurrent shocks and consequently reducing their sporting activities.[55] The previously discussed registry study of athletes with ICDs participating in organized sporting activity showed that about 30% of the patients who received a shock ended up stopping all sporting activities, underscoring the potential for adverse psychological sequelae of an ICD shock.[39]

Given the lack of substantial evidence supporting the Bethesda and ESC recommendations for athletic participation in patients with ICDs, it is important to recognize patient/family autonomy and respect their rights to make a well informed decision regarding continuation of athletics, thus, paving the way for a shared decision-making engagement. Contrary to the

myth that such shared decision-making is not possible, as it is assumed that “all athletes will always choose to remain an athlete”, has not been our observation at all over the past 15 years. Instead, it was shown that one in five athletes chose self-disqualification from competitive sports when given a choice after carefully explaining the individual risks and benefits of participation.[51]

Section III. Practical considerations of ICDs in athletes

Section IIIA. Single chamber vs. dual chamber ICDs

Since inappropriate shocks are a major concern in athletes with ICDs who remain active, some electrophysiologists propose the use of a dual-chamber ICD over single-chamber devices to improve the specificity of arrhythmia detection.[56] However, other studies have failed to show any significant difference in the incidence of inappropriate ICD shocks in patients with dual-chamber ICDs as compared to those with single-chamber devices.[57, 58] Moreover, dual-chamber ICDs may lead to a higher incidence of early or late post-operative complications, along with increased complexity of implantation and follow-up.[59] In addition, athletes typically represent a generally younger population, and the less number of leads at initial implantation may help in reducing the number of leads that need extraction or replacement in the future, thus reducing the potential for long-term morbidity and mortality. [35] Accordingly, unless the underlying disease process may benefit from atrial pacing, we advise a single-lead ICD system for athletes.

Section IIIB. ICD programming: can we reduce inappropriate shocks?

ICDs recognize malignant arrhythmias by closely monitoring the morphology and ventricular rate of the patient. This may in turn lead to a high frequency of inappropriate shocks in athletes due to the high incidence of faster heart rates (sinus tachycardia or supraventricular tachycardias), lead noise, or sensing issues during intense physical activity. Thus, one must be careful in activating lower thresholds in these patients as they may lead to an increase in inappropriate shocks. Programming additional differentiating parameters to improve the device's specificity in picking up ventricular arrhythmias (characterized by sudden onset, instability, and wide-complex morphology) has been suggested, but this may result in decreased sensitivity and so may be reserved as a second line option in patients with a high frequency of inappropriate shocks.[35]

Certain ICD programming maneuvers have been attempted to decrease the rate of inappropriate shocks. These include trying at least one attempt of anti-tachycardia pacing to stop arrhythmias in the ventricular fibrillation (VF) zone while the device is charging[60], increasing the VF zone threshold to >210 to 220 beats per minute, and extending the detection time at these rates.[61] Apart from these measures, using long-term ECG recordings to calculate rate responsiveness during training and availing dual sensors (minute ventilation + activity) to help differentiate physical activities[62] may also have the potential to reduce the rate of inappropriate shocks in athletes with ICDs. If chronotropic incompetence or symptomatic bradycardia from the use of bradycardic drugs is suspected in these patients, atrio-ventricular sequential pacing through dual-chamber ICD is suggested in order to decrease symptoms from continued ventricular pacing.[35, 62]

Section IIIC. Subcutaneous ICD (S-ICD)

Due to various lead concerns in athletes with ICDs there has been a considerable interest in the newest generation subcutaneous ICD (S-ICD) systems.[63, 64] Studies on S-ICDs indicate a high efficacy but relatively low specificity and this could translate to a significant increase in the number of inappropriate shocks in these individuals.[65]. Another limitation to S-ICDs would be their inability to pace and therefore these cannot be used in athletes with potentially pace-terminable arrhythmias. This area is clearly in need of further research and observation prior to further consideration in athletes as their primary source of shock therapy, which can literally be lifesaving.

Section IIID. Factors that may help reduce risk in athletes with ICD who chose to compete

It has been proposed that habitual exercise may decrease the risk of SCD during exercise by 7-fold, especially amongst people who exercise infrequently i.e., less than once a week.[66] The risk of SCD however, appears to be independent of the level of athletic competition (i.e., high school, college, or professional).[9] In these patients with ICDs, compliance with target heart rates may also decrease the risk of life-threatening arrhythmias and ischemia during vigorous physical exercise or training.[67] Monitoring and recognizing target heart rates may also decrease shocks which are due to sinus tachycardia[56] Whether the use of mechanical barriers such as a Kevlar vest could decrease the risk associated with contact sports is unknown.[45] The use of beta-blockers to counteract the catecholamine surge, ensuring adequate hydration, and electrolyte replacement during intense training and physical exertion all may reduce the risk of SCD by decreasing the intrinsic arrhythmogenicity of the ventricular myocardium during a period of activity.[68] However, continued prospective/registry-based data are needed to further evaluate and validate these strategies.

Conclusion

Athletes with predisposing cardiac disease for SCD represent a unique segment of the general population, who despite their excellent physical condition, are at an increased risk of arrhythmias and SCD by the sheer virtue of the intensity and duration of the physical exercise they engage in. Current international recommendations preclude athletes with ICDs from participating in the vast majority of competitive sports. However, these guidelines are over a decade old, and are being reviewed, revised, and updated and it is anticipated that the former “if in doubt, kick them out” position will be replaced increasingly with an individualized, shared-decision making approach. Although there is some preliminary data supporting the safety of athletes with ICDs when participating in organized sports, much progress is yet to be made to ensure safety in these patients and larger trials and innovation are needed.

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Key Points

1. Athletes with ICDs are faced with many physical and psychological challenges posed by their passion to pursue exercise and training despite the restrictive recommendations based on expert opinion, rather than objective evidence.
2. Current international guidelines (European Society of Cardiology (ESC) and Bethesda #36) for athletes with underlying heart disease recommend only moderate, leisure-time physical activity in patients with an ICD. Thus, making athletes with ICDs ineligible for most competitive sports. However, new North American guidelines are re-assessing these 2005-based recommendations and a new set of 2013 disease-specific guidelines such as those for patients with long QT syndrome (LQTS) are embracing a shared decision making approach to this issue rather than a default disqualification.
3. The efficacy of ICDs in terminating a potentially lethal arrhythmia under the extreme conditions of competitive sports associated with metabolic and autonomic changes like catecholamine surges, dehydration, electrolyte derangements, and myocardial ischemia is unknown. However, no athletic deaths have occurred in nearly 400 athletes with ICDs in over three years of follow-up.
4. There is preliminary data from registry based studies and surveys demonstrating the relative safety of athletes engaging in vigorous physical activity or organized sporting activities.
5. Inappropriate shocks from the ICDs and potential damage to the integrity of the ICD system during engagement in intense physical activity or contact sports remains as an area of concern for athletes and clinicians.

Figure 1. Classification of sports

This classification is based on peak static and dynamic components achieved during competition. It should be noted, however, that higher values may be reached during training. The increasing dynamic component is defined in terms of the estimated percent of maximal oxygen uptake (MaxO₂) achieved and results in an increasing cardiac output. The increasing static component is related to the estimated percent of maximal voluntary contraction (MVC) reached and results in an increasing blood pressure load. The lowest total cardiovascular demands (cardiac output and blood pressure) are shown in green and the highest in red. Blue, yellow, and orange depict low moderate, moderate, and high moderate total cardiovascular demands. *Danger of bodily collision. †Increased risk if syncope occurs. [15] Reproduced with permission from Elsevier Limited – License number: 3595531241298 obtained on 3/24/15

Table 1 *

2005 Bethesda Conference #36 (BC#36) and 2005 European Society of Cardiology (ESC) recommendations for participation in competitive sport [69]

Condition	Bethesda Conference #36 (BC#36)	European Society of Cardiology (ESC)
Hypertrophic cardiomyopathy	Exclude athletes with probable or definitive clinical diagnosis from all competitive sports except perhaps class IA sports. Genotype-positive/phenotype-negative athletes may still compete.	Exclude all athletes irrespective of genotype or symptoms from all competitive sports. A positive genetic test itself is self-sufficient for a comprehensive disqualification.
Arrhythmogenic right ventricular cardiomyopathy	Exclude all athletes with probable or definitive diagnosis from all competitive sports except IA.	Same as HCM
Long QT syndrome	Exclude any athlete with previous cardiac arrest or syncopal episode from competitive sports. Asymptomatic LQTS athletes with overt QT prolongation restricted to IA sports. Genotype positive but phenotype negative LQTS athletes given the OK to play.	Same as HCM. All LQTS athletes from all sports period.
Short QT syndrome	Exclude from all competitive sport except those of low intensity	-
Brugada syndrome	Exclude from all competitive sport except those of low intensity (Class IA)	Exclude from all competitive sport
Catecholaminergic polymorphic ventricular tachycardia	Exclude all patients with clinical diagnosis from competitive sport. Genotype-positive/phenotype-negative patients may still compete in low-intensity sport (Class IA)	Exclude all athletes irrespective of genotype or symptoms from all competitive sports.

* Adapted with permission from "Sudden cardiac death among competitive adult athletes: a review" by Pugh et al. - License number: 3595581467205 obtained on 3/24/15

Table 2

Potential concerns faced by athletes with ICDs during engagement in sporting activities

Concerns in athletes with ICDs
Transient loss of consciousness causing serious injury/death during a ICD shock
Damage to the integrity of the ICD/pacemaker system in athletes engaging in contact sports
Lead fracture due to repeated arm movements and costo-clavicular crush in left handed athletes
VT storm due to repeated shocks delivered during high catecholamine surge
Unknown efficacy of ICD therapy in conditions associated with vigorous exercise
Negative psychological impact due to fear of ICD shocks and sudden death
High frequency of inappropriate shocks due to increased lead noise or T wave over-sensing
Possibility of inducing ventricular arrhythmias if an inappropriate shock is delivered on the t wave