It is well known that physical activity reduces cardiovascular morbidity and mortality through a wide variety of mechanisms, although it is unclear whether the intensity of physical activity in competitive athletes promotes health benefits beyond those of moderate activities.

Physical activity also contributes to psychological well-being in those affected by cardiovascular disease.
• When first introduced, pacemakers were simply life-saving devices that provided a fixed pacing rate during bradycardic episodes.

• During the last years, significant advances in the field of cardiac pacing have resulted in the introduction of pacemakers capable of varying pacing rates in response to metabolic and physical stimuli.

• The advances in rate-response technology and the increasing rate of pacemaker implantation underscores the need for an understanding of current pacemaker technology and how these devices impact on the principles of exercise prescription for patients with pacemakers.
Before a pacemaker-dependent patient starts a cardiac rehabilitation program, an exercise test should be performed for

- Verification of proper pacemaker function, including
  a) adapted changes in rate
  b) reliable sensing and pacing, which might change with breathing, changes in posture and with motion
  c) preservation of AV synchrony
- Evaluation of residual symptoms or development of new, exercise-induced symptomatology
- Programming and optimization of specific parameters that vary as a function of the heart rate (AV delays and adaptable PVARP)
- Find electrophysiologic changes due to exercise (retrograde conduction present during exercise and absent at rest)

**Programmable parameters before exercise**

- Atrioventricular synchronization during exercise
  - The Maximum Tracking Rate (2:1 block point)

- Specific programming to preserve atrioventricular synchronization during exercise
  - Adaptable atrioventricular delay
  - PVARP → auto
  - Maximum synchronous rate
  - Atrial sensitivity → requires a flawless quality of atrial sensing
- Rate responsive pacing
ATRIOVENTRICULAR SYNCHRONIZATION DURING EXERCISE

• The Maximum Tracking Rate (2:1 block point)

  It must be set as high as possible to enable the 1:1 tracking of the sinus P waves over the entire range of rates that might be observed in any given patient.

• The TARP duration (AV delay + PVARP) must, therefore, be shortened during exercise, which can be achieved by programming an automatic shortening of AV delay and PVARP during exercise.

• Adaptable atrioventricular delay (A-V delay)

  In the healthy heart, the PR interval shortens physiologically during exercise.

  The adaptation of the AV delay that can occur when the pacemaker operates in DDDR, DDD, DDIR or VDD modes, simulates physiological response to exercise.
Some patients suffer from chronotropic insufficiency and inadequate increase in heart rate during physical activity. This inability to increase the heart rate with exercise can be associated with symptoms such as dyspnea, fatigue or limited exercise capacity.

Pacemakers include sensors capable of monitoring the activity level and accelerate the pacing rate accordingly.

Its aim, in the presence of chronotropic insufficiency, is to ensure an increase in cardiac output that is, as physiologic as possible, and corresponding to the instantaneous metabolic needs imposed by exercise.

Each device manufacturer offers its particular sensor and programming of the rate responsiveness.
• Monitoring of physical activity by a piezoelectric quartz or by an accelerometer, and minute-ventilation, using the bio-impedance technique.

General Recommendations during Exercise

• Carry Medical ID at All Times

• Always Wear a Heart Monitor
• Pacemakers typically have a rate cutoff, and getting too close to this upper limit should be avoided.

• Typically, it is advised to maintain at least a 10 bpm margin between exercise heart rate and the cutoff limit. If heart rate accelerates too quickly, patient is advised to tone down his workout and breathe deeply to lower his heart rate to a safe level before resuming exercise.
• A safe workout should always include both a warm up and cool down period.

• Advise patient not to jump right into a run and not to sit down right away after a workout.

• Start and end any run with a light walk.

• If strength exercises are being done, 5-10 light minutes on the exercise bike to cool down after workout is preferred.

• **Avoid Full Contact Sports**

  • A pacemaker won’t limit from most forms of exercise, but contact sports should be avoided.
  
  • Taking hits or falling can dislodge pacemaker or shift the leads intracardiac.
  
  • Rhythmic activities like walking, running, cycling or swimming are much safer.
• Generally, athletes with permanent pacemakers should be cleared for athletic participation if there are no limiting structural heart conditions or symptoms \((\text{Class I; Level of Evidence C})\).

• Athletes who are completely pacemaker dependent should not engage in sports in which there is a risk of collision that could result in damage to the pacemaker system \((\text{Class I; Level of Evidence C})\).

• Athletes treated with a pacemaker who are not pacemaker dependent may participate in sports with a risk of collision or trauma if they understand and accept the risk of damage to the pacemaker system and they have no structural heart disease that precludes participation \((\text{Class I; Level of Evidence C})\).

• For athletes with permanent pacemakers, protective equipment should be considered for participation in contact sports that have the potential to damage the implanted device \((\text{Class I; Level of Evidence C})\).
ICDs & Exercise

• 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.

• The two most widely accepted guidelines used for determining the eligibility to participate in competitive sports are from the United States-36th Bethesda conference (BC #36), and Europe-the ESC expert consensus document.

• 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.
Current international guidelines 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 as so-called class IA sports (billiards, bowling, cricket, curling, golf, and riflery).
• For athletes with ICDs, all moderate and high intensity sports are contraindicated and only class IA sports are permitted.

• 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.

• 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.
Potential Risks

• Intense physical exertion increases the risk of SCD by almost 2.5 times in patients with underlying arrhythmogenic cardiac disease.

• ICD efficacy in terminating a potentially lethal arrhythmia under the extreme conditions of competitive sports, with the associated metabolic and autonomic changes, as well as possible myocardial ischemia, is unknown.

• Sports with physical contact may result in damage to the ICD, thereby preventing its normal function.

Potential Risks

• In athletes with left hand dominance, extreme arm movements can cause ICD lead fracture due to costo-clavicular crush.

• A variety of conditions that occur during exercise like sinus tachycardia, SVT 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.

• The transient loss of consciousness from exercise-induced arrhythmias or inappropriate/appropriate ICD shocks may pose a serious risk of severe injury or death to the athlete as well as the spectators.
Potential Risks

- Inappropriate shocks can have a negative psychological impact on the athlete.

- 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.

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. (follow up of 2.2 years)

• In addition, the incidence of lead malfunction was not higher in athletes with ICDs compared to published rates in non-athletes.

• Many athletes with ICDs can engage in vigorous competitive sports without physical injury or failure to terminate the arrhythmia despite the occurrence of both inappropriate and appropriate shocks in a small number.


Conclusion: Based on the current literature, ET in patients with an ICD seems to be safe and is not associated with increased risk of shocks. ET improves aerobic capacity in ICD patients, while effects on anxiety, depression and quality of life are still under debate.
Conclusions We found no evidence of increased ICD shocks in patients with HF and reduced left ventricular function who underwent exercise training. Exercise therapy should not be prohibited in ICD recipients with HF.

**ICD programming: can we reduce inappropriate shocks?**

- Programming additional differentiating parameters to improve the device’s specificity in picking up ventricular arrhythmias as:
  - sudden onset
  - instability
  - wide-complex morphology

- but → decreased sensitivity

so may be reserved as a second line option in patients with a high frequency of inappropriate shocks
ICD programming: can we reduce inappropriate shocks?

- At least one attempt of anti-tachycardia pacing (ATP) to stop arrhythmias in the ventricular fibrillation (VF) zone while the device is charging

- Increasing the VF zone threshold to >210 to 220 beats per minute

- Extending the detection time at these rates.

ICD programming: can we reduce inappropriate shocks?

- Using long-term ECG recordings to calculate rate responsiveness during training and availing dual sensors (minute ventilation + activity) to help differentiate physical activities.
Is there any role for S-ICD ???

• There has been a considerable interest in the newest generation subcutaneous ICD (S-ICD) systems.

• 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.

• Another limitation to S-ICDs would be their inability to pace and therefore these cannot be used in athletes with potentially pace-terminable arrhythmias.

• Participation in sports classified as IA for athletes with an ICD is reasonable if they are free of episodes of ventricular flutter or ventricular fibrillation requiring device therapy for 3 months *(Class IIa; Level of Evidence C)*.
• Participation in sports with higher peak static and
dynamic components than class IA may be considered
if the athlete is free of episodes of ventricular flutter
or ventricular fibrillation requiring device therapy for
3 months.

• The decision regarding athletic participation should
be made with consideration of, and counseling of, the
athlete regarding the higher likelihood of appropriate
and inappropriate shocks and the potential for
device-related trauma in high-impact sports (Class IIb;
Level of Evidence C).

Take Home Message

• Athletes with pacemakers & 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.

• Proper programming maneuvers along with
recent advances in device technology & exercise
algorithms can gives us more room for better
exercise lifestyle for many patients.
Take Home Message

- Current international guidelines 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.

Take Home Message

- 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 (ICD Safety Registry).
Take Home Message

• There are various data from registry based studies and surveys demonstrating the relative safety of athletes engaging in vigorous physical activity or organized sporting activities.

• Inappropriate shocks from the ICDs and potential damage to the integrity of the ICD system during intense physical activity remains as an area of concern for athletes and clinicians.

Thank you