# Refining Electrocardiography Interpretation Criteria in Elite Athletes

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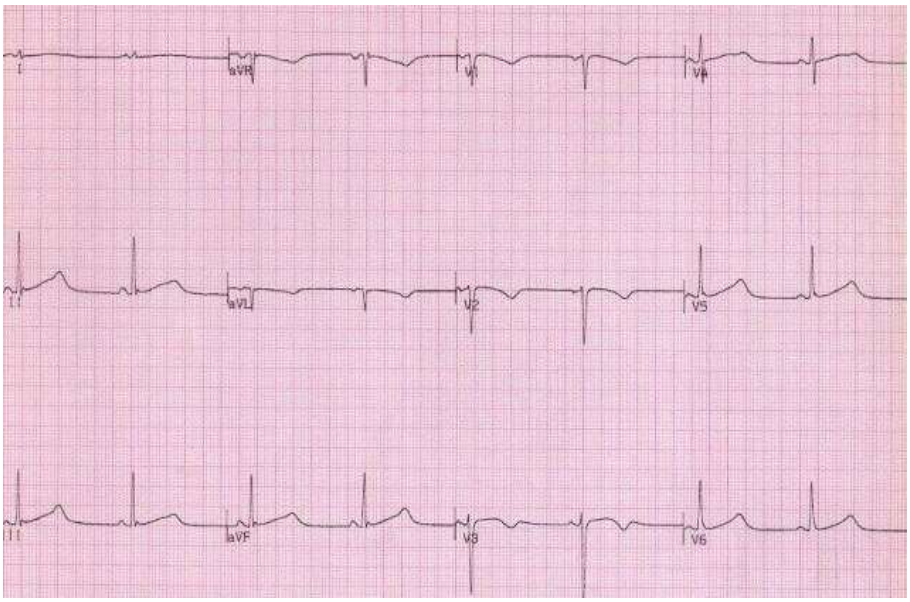
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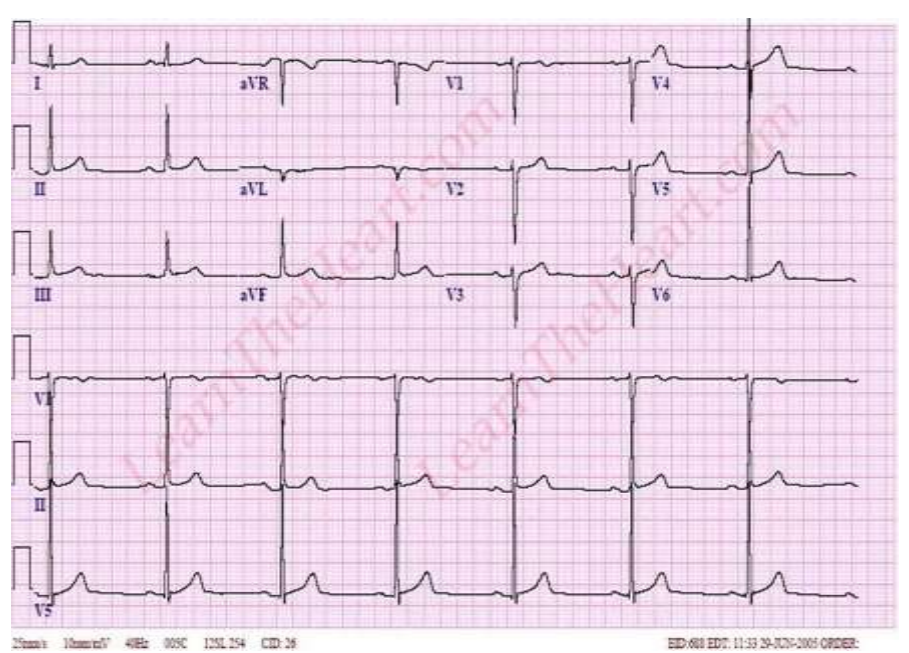
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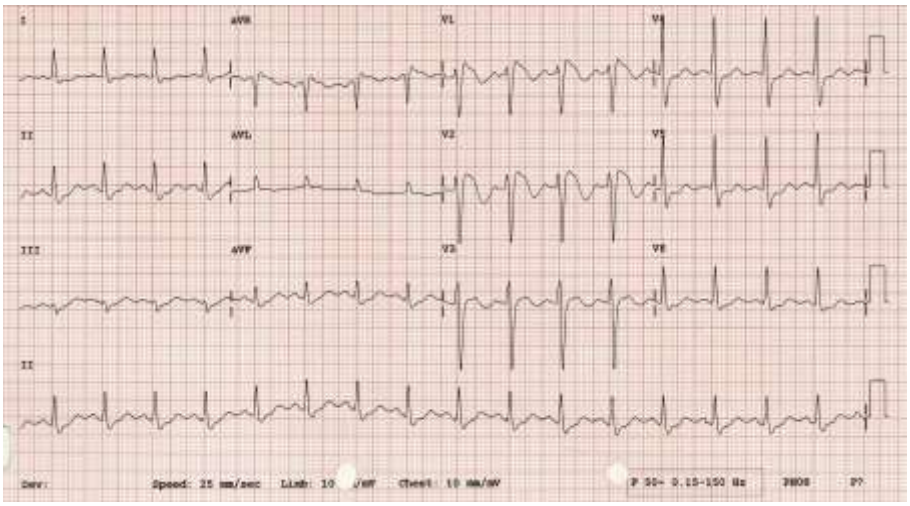
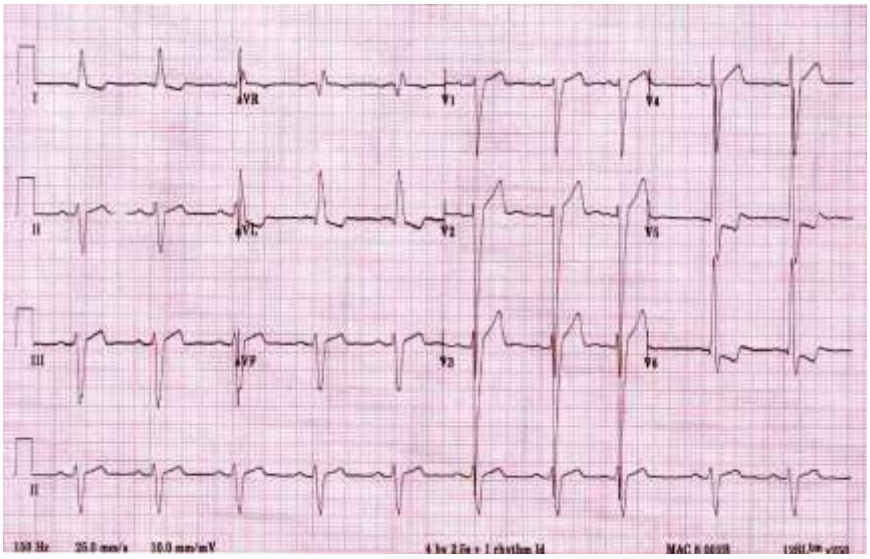
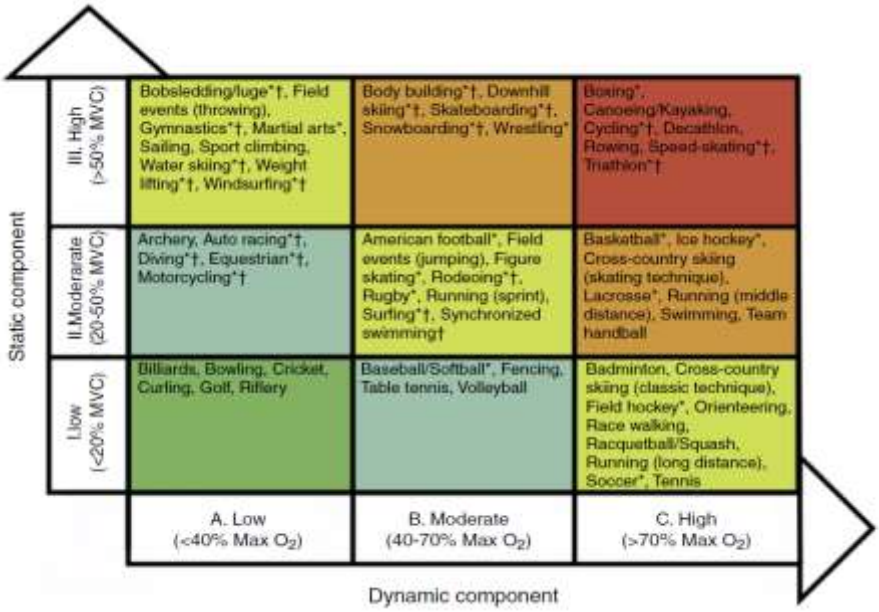




## Refining ECG Criteria in Athletes

- Why Should We Screen Athletes?
- What & How To Screen?
- ECG Abnormalities In Athletes
- When To Raise Red Flags?
- Value Of Screening In Practice
- Dilemma

## Sports Classification based on Static and Dynamic Components



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## Athletes and Sudden Cardiac Death

- SCD is the leading cause of mortality in young athletes.
- Majorly due to diverse inherited & congenital cardiac diseases.
- Screening is necessary to identify those at high risk, thus saving lives.
- Competitive athletes have increased risk of SCD (2-2.8 fold).

## Athletes and Sudden Cardiac Death

- Prevalence of CV diseases predisposing to SCD in athletes ranges 0.2 - 0.7% .
- Mechanism of SCD is usually ventricular arrhythmia.
- **How**: Exercise induced catecholamine surge acting on arrhythmogenic substrate.
- **Precipitators**: Dehydration, pyrexia, electrolyte imbalance& platelet aggregation.

## Athletes and Sudden Cardiac Death

Competitive Athletes are 2.5 fold greater risk for SCD in comparison with their age& gender matched counterparts

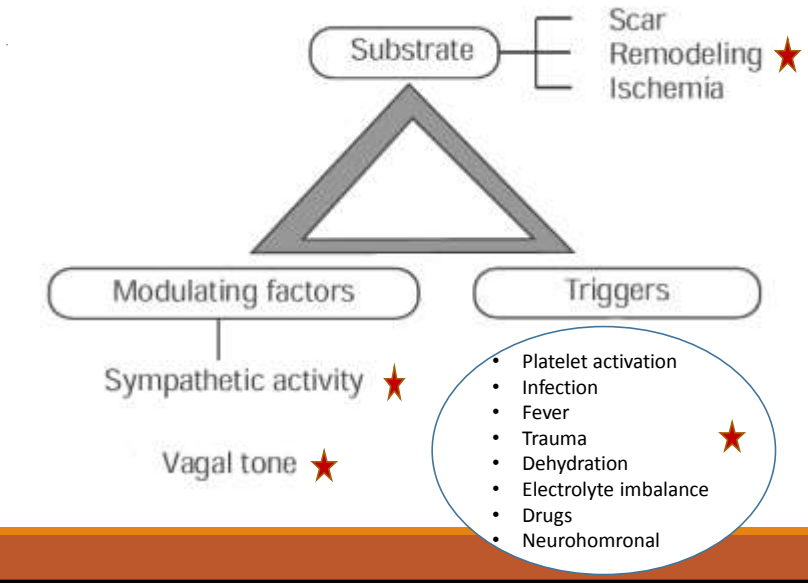
**Prevalence of cardiovascular diseases at risk for sudden cardiovascular death in young athletes**

| Ref. | Population | Prevalence (%) |
|---|---|---|
| Fuller et al.[26] | 5617 high school athletes (USA) | 0.4 |
| Corrado et al.[13] | 42,386 athletes age 12–35 (Italy) | 0.2 |
| Wilson et al.[27] | 2720 athletes and children age 10–17 (UK) | 0.3 |
| Bessem et al.[28] | 428 athletes age 12–35 (Netherlands) | 0.7 |
| Baggish et al.[21] | 510 collegiate athletes (USA) | 0.6 |

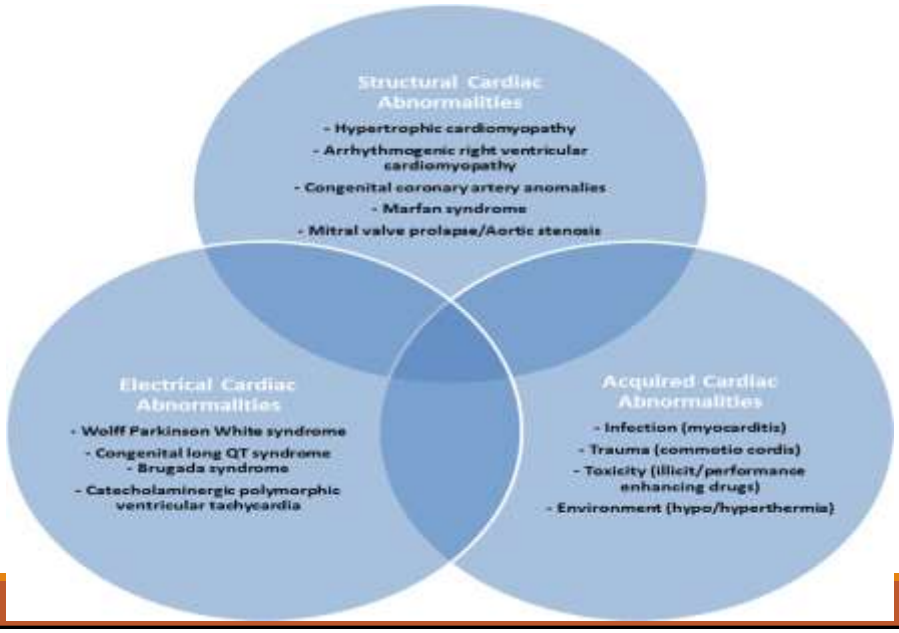
**Incidence of sudden cardiac death/arrest in young people and athletes according to different reporting systems**

| Study population | Ref. | Study design and reporting system | Incidence (person-years) |
|---|---|---|---|
| US Military (age 18–35) | Eckart et al.[31] | Retrospective, mandatory | 1:9000 |
| Italian Athletes (age 12–35) | Corrado et al.[32] | Prospective, mandatory | 1:25,000 |
| US Adolescents (age 12–19) | Atkins et al.[33] | Prospective, EMS | 1:27,000 |
| US Children (age 10–14) | Chugh et al.[22] | Prospective, EMS/ Hospitals | 1:58,000 |
| US Athletes (age 12–35) | Maron et al.[19] | Retrospective, public media reports | 1:160,000 |

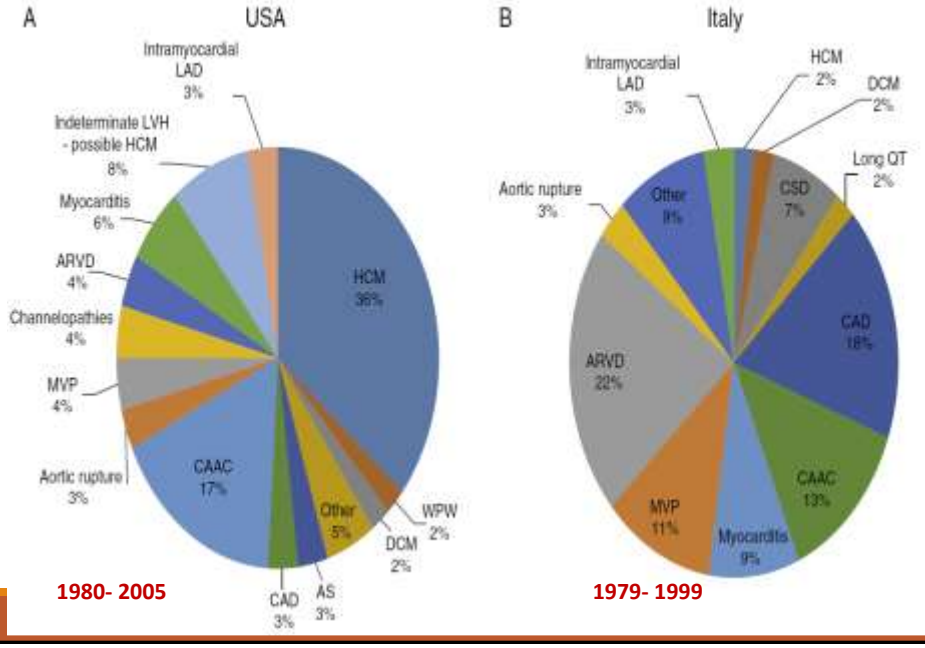
## Recipe for Arrhythmia




## Common Causes of SCD in Athletes



## Causes Of Sudden Cardiac Death in Athletes

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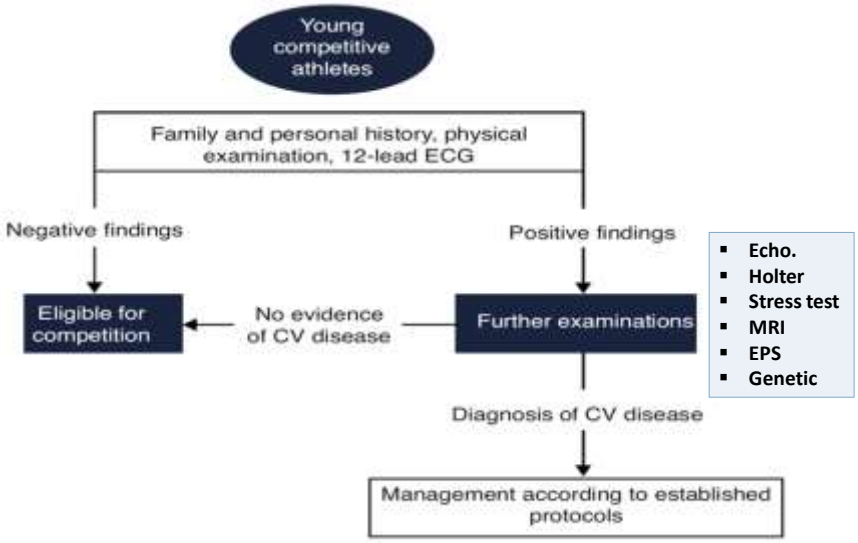
## The 12-Element AHA Recommendations for Pre-participation Cardiovascular Screening of Competitive Athletes

| |
|---|
| **Personal history** |
| 1. Exertional chest pain/discomfort |
| 2. Unexplained syncope/near-syncope |
| 3. Excessive exertional and unexplained dyspnea/fatigue, associated with exercise |
| 4. Prior recognition of a heart murmur |
| 5. Elevated systemic blood pressure |
| **Family history** |
| 6. Premature death (sudden and unexpected) <50 yr-old due to heart disease |
| 7. Disability from heart disease in a close relative <50 years of age |
| 8. HOCM, DCMP, long-QT syndrome, Marfan syndrome, or clinically important arrhythmias |
| **Physical examination** |
| 9. Heart murmur |
| 10. Femoral pulses (to exclude aortic coarctation) |
| 11. Physical stigmata of Marfan syndrome |
| 12. Brachial artery blood pressure (sitting position) |

## ESC Screening Protocol for Competitive Athletes



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## Electrical Changes in Athletes

- **What**: ST-T changes, channelopathies, bradycardia, ERP & hypertrophy.
- **Why**: Inherited, Congenital, ANS conditioning: increased vagal tone & sympathetic withdrawal/activation.
- **Cellular changes**: Functional down regulation of K currents & aberrant Ca handling
  - Frequent spontaneous activity
  - Prolongation of AP duration
- These changes could eventually lead to ventricular arrhythmia

## The ESC criteria for ECG findings in athletes

| Group 1: Common and Training-Related Electrocardiographic Changes | Group 2: Uncommon and Training-Unrelated Electrocardiographic Changes |
|---|---|
| Sinus bradycardia | T-wave inversion |
| First-degree atrioventricular block | ST-segment depression |
| Incomplete right bundle branch block | Pathological Q waves |
| Early repolarization | Left atrial enlargement |
| Isolated QRS voltage criteria for left ventricular hypertrophy | Right atrial enlargement |
| | Left axis deviation |
| | Right axis deviation |
| | Right ventricular hypertrophy |
| | Ventricular pre-excitation |
| | Left bundle branch block |
| | Right bundle branch block |
| | Long QTc interval (>440 ms in males; >460 ms in females) |
| | Short QTc interval (<380 ms) |
| | Brugada-like early repolarization |

## The American (Seattle) criteria for Normal ECG findings in athletes

| |
|---|
| Sinus bradycardia ≥ 30 bpm |
| Sinus arrhythmia |
| Ectopic atrial rhythm |
| Junctional escape rhythm |
| First-degree AV block (PR > 200 ms) |
| Mobitz I second-degree AV block |
| Incomplete right bundle branch block |
| Isolated voltage criteria for LVH (absence of left atrial enlargement, left axis deviation, ST depression, T-wave inversion, pathologic Q waves) |
| Early repolarization (ST elevation with T-wave inversion in V1-V4) |

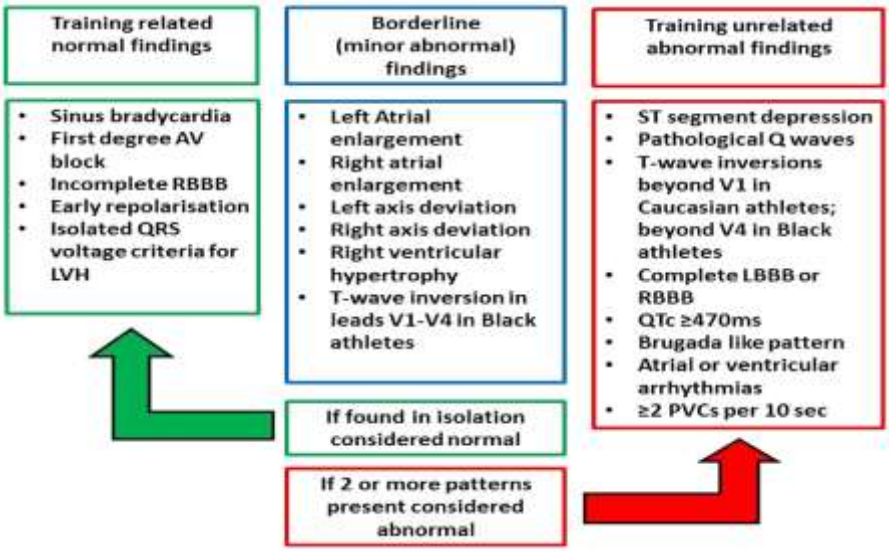
## The American (Seattle) criteria for Abnormal ECG findings in athletes

| |
|---|
| T-wave inversion (in two or more leads V2-V6, II, aVF, or I and aVL |
| ST depression (≥ 0.5 mm in two or more leads) |
| Sinus tachycardia |
| Pathologic Q waves (> 3 mm in depth or > 4 msec in duration in two or more leads except III and aVR) |
| Left bundle branch block |
| Left axis deviation (-30° to -90°) |
| Left atrial enlargement |
| Right ventricular hypertrophy (RV1 + SV5 > 10.5 mm and right axis deviation) |
| Ventricular pre-excitation |
| Brugada-like ECG pattern |
| Sinus bradycardia < 30 bpm |
| PVCs (≥ two PVCs per 10-second tracing or nonsustained ventricular tachycardia |

## Caveats in the ECG screening Criteria

- High false positive rate (10-20%)
- Disqualifying healthy athletes from sports participation
- Appeal proposals
- Misleading the epidemiology of CV conditions affecting athletes
- Cost effectiveness

## Refined American criteria for Abnormal ECG findings in athletes




## Comparison of ECG interpretation in screening athletes

| | Combined (n=2491) |
|---|---|
| Prevalence of an abnormal ECG using ESC recommendations | 555 (22.3%) |
| Prevalence of an abnormal ECG using Seattle Criteria | 289 (11.6%) |
| Prevalence of an abnormal ECG using Refined Criteria | 132 (5.3%) |
| Number of identified conditions associated with SCD | 10 (7 HCM; 3 WPW) |
| FPR when using ESC recommendations | 21.9% |
| FPR when using Seattle Criteria | 11.2% |
| FPR when using Refined Criteria | 4.9% |

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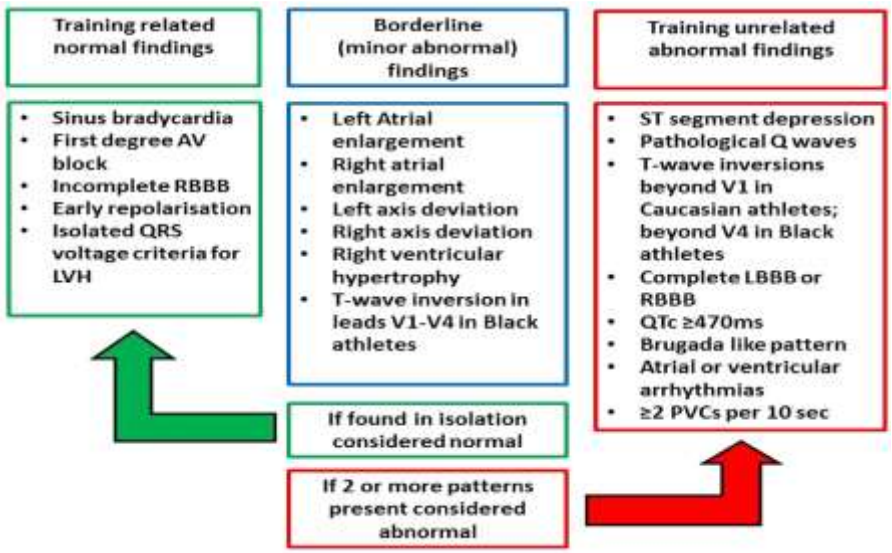
| ECG Abnormalities | 36th Bethesda Conference (ACC/AHA) | ESC |
|---|---|---|
| **WPW** | Athletes without structural heart disease, without a history of palpitations, or without tachycardia can participate in all competitive sports. | Athletes without structural heart disease, without a history of palpitations, or without tachycardia can participate in all competitive sports. |
| | In athletes with symptoms, EP study and ablation are recommended. Return to competitive sports is allowed after corrective ablation, provided that the ECG has normalized. | In athletes with symptoms, EP study and ablation are recommended. Return to competitive sport is allowed after corrective ablation, provided that the ECG has normalized. |
| **LQTS** | Exclude any athlete with a previous cardiac arrest or syncopal episode from competitive sports. | Exclude any athlete with a clinical or genotype diagnosis from competitive sports. |
| | Asymptomatic patients restricted to competitive low-intensity sports. | |
| | Genotype-positive/phenotype-negative athletes may still compete. | |
| **Brugada Syndrome** | Exclude from all competitive sports except those of low intensity. | Exclude from all competitive sports. |

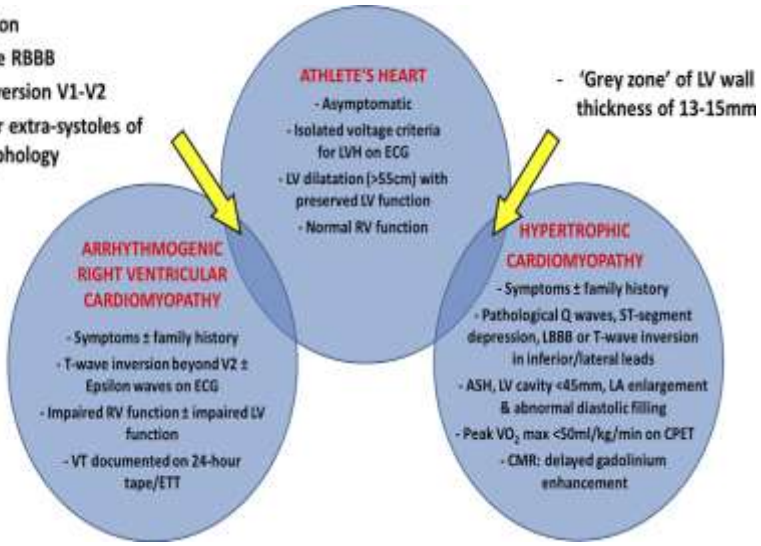
| ECG Abnormalities | 36th Bethesda Conference (ACC/AHA) | ESC |
|---|---|---|
| CPVT | Exclude all patients with a clinical diagnosis from competitive sports. | Exclude all patients with a clinical diagnosis from competitive sports. |
| | Genotype-positive/phenotype-negative patients may still compete in low-intensity sports. | Genotype-positive/phenotype-negative patients are also excluded. |
| ARVC | Exclude athletes with a probable or definitive diagnosis from competitive sports. | Exclude athletes with a probable or definitive diagnosis from competitive sports. |

## Refined American criteria for Abnormal ECG findings in athletes



## Physiology vs. Pathology: 'Athlete's Heart' vs. 'HCM & ARVC'

- RV dilatation
- Incomplete RBBB
- T-wave inversion V1-V2
- Ventricular extra-systoles of LBBB morphology




- 'Grey zone' of LV wall thickness of 13-15mm

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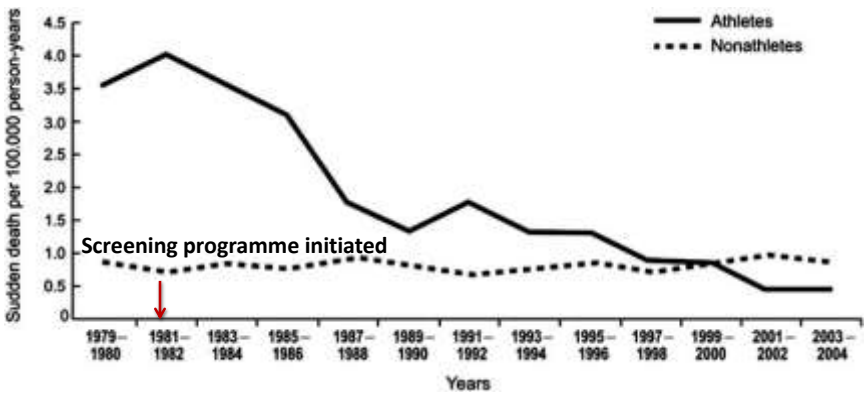
## ECG Screening for Competitive Athletes: Meta-analysis

- Meta-analysis of 15 articles reporting on 47,137 athletes.
- CV conditions detected were 160 (0.3%) or (1 in 294)
- WPW was the highest prevalence (67/160, 42%)
- Sensitivity and specificity: ECG 94%/93%, history 20%/94% & PE 9%/97%
- False positive rate: ECG (6%), history (8%) & physical exam (10%)

## ECG at initial evaluation

## ECG at Holter Monitoring




Annual incidence rate of SCD/100,000 person, among screened competitive athletes and unscreened non-athletes 12–35 years of age in the **Veneto in Italy**, 1979 - 2004.

The incidence of SCD declined by 89% in screened athletes (P <0.001). However, the incidence of SCD did not change over that time in unscreened non-athletes.

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## Dilemma!

- Real prevalence & causes of SCD in athletes
- Normal, adaptive and maladaptive variants of CV response in athletes
- Pre-participation screening programs standardization
- 'Certainly' vs. 'not sure' findings
- False positive & false negative results, poly-investigations
- When to re-engage in competitive sports
- Cost-effectiveness

## Take Home Message

- SCD in athletes is 2.8 fold more than non-athletes counterparts.
- Victims of SCD are often entirely asymptomatic before their initial presentation and demonstrate only subtle abnormalities on investigation.
- Pre-participation screening of competitive athletes is a preventive strategy that should be implemented routinely and effectively.
- This includes: History, Examination & ECG as initial step, followed by Echocardiogram and other cardiovascular investigations if needed.

## Take Home Message

- The most effective strategy for screening for CV disease in athletes is ECG
- The refined ECG criteria improved the detection of true positive athlete cases
- ECG is 5 times > sensitive than history, 10 times > sensitive than physical exam
- ECG has higher positive & lower negative likelihood & lower false positive rate
- 12-lead ECG should be considered in standard screening for athletes while the use of history and physical examination alone should be re evaluated

## Suggested Reading


- ✓ Dores H, Freitas A, Malhotra A, et al. The hearts of competitive athletes: An up-to-date overview of exercise-induced cardiacadaptations. Rev Port Cardiol. 2015 Jan;34(1):51-64.
- ✓ Brosnan M, La Gerche A, Kumar S, et al. Modest agreement in ECG interpretation limits the application of ECG screening in young athletes. Heart Rhythm. 2015 Jan;12(1):130-6.
- ✓ Sharma S, Merghani A, Gati S. Cardiac screening of young athletes prior to participation in sports: difficulties in detecting the fatally flawed among the fabulously fit. JAMA Intern Med. 2015 Jan 1;175(1):125-7.
- ✓ Riding NR, Sheikh N, Adamuz C, et al . Comparison of three current sets of electrocardiographic interpretation criteria for use in screening athletes. Heart. 2015 Mar;101(5):384-90.
- ✓ Lisman KA. Electrocardiographic Evaluation in Athletes and Use of the Seattle Criteria to Improve Specificity. Debakey Cardiovasc J. 2016 Apr-Jun;12(2):81-5.
- ✓ Harmon KG, Zigman M, Drezner JA. The effectiveness of screening history, physical exam and ECG to detect potentially lethal Cardiac disorders in athletes: a systematic review/meta-analysis. J Electrocardiol. 2015 May-Jun;48 (3):329-38.
- ✓ Machado M, Vaz Silva M. Benign and pathological electrocardiographic changes in athletes. Rev Port Cardiol. 2015 Dec;34 (12):753-70.