Pre-Participation Cardiac Screening in Athletes: What is the Evidence
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Objectives

To provide an overview of sudden cardiac death in athletes.

To compare the effectiveness of accepted screening models.

To provide a realistic view of some of the concerns with ECG screening.
Sudden Cardiac Death in Athletes
# Incidence of Sudden Cardiac Death

<table>
<thead>
<tr>
<th>POPULATION</th>
<th>AGE</th>
<th>DURATION</th>
<th>INCIDENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organised high school and college athletes</td>
<td>13-17</td>
<td>12 years</td>
<td>0.5/100,000</td>
</tr>
<tr>
<td>Competitive athletes</td>
<td>14-35</td>
<td>25 years</td>
<td>2/100,000/yr</td>
</tr>
<tr>
<td>Marathon (London)</td>
<td>Mean 42</td>
<td>26 years</td>
<td>2.2/100,000 runs</td>
</tr>
<tr>
<td>Rhode island jogger</td>
<td>30-65</td>
<td>7 years</td>
<td>13/100,000/yr</td>
</tr>
</tbody>
</table>

1. Roberts WO. JACC. 2013; 62: 1298  
2. Corrado D. JAMA. 2006; 296: 1953  
Sudden Death in Young Athletes
Sudden Cardiac Death in Sport

Hypertrophic Cardiomyopathy

Arrhythmogenic right ventricular cardiomyopathy
Coronary arteries and aorta
Sudden Cardiac Death with a Normal Heart

LQTS

Brugada

WPW
Cause of Death in Senior Athletes

- Coronary artery disease: 80%
- Other causes: 5% each
Triggers for Sudden Cardiac Death

- Dehydration
- Adrenergic surges
- Electrolyte imbalance
- Acid/base disturbance
Sudden Cardiac Death in Athletes
Sudden Deaths in Triathlon
Harris K et al ACC 2016

USA Triathlon Experience 1985-2015

1 in 67,000. 80% non traumatic.

35% in first time participants

85% in males

Mean age 47 years old

70% of all deaths in swimming
Deaths During Swimming

• **Drowning**
  – Precipitated by water aspiration
  – Kicked and knocked unconscious

• **Lung Problem**
  – Swimming Induced Pulmonary Edema (SIPE)
  – Asthma attack
  – Anaphylaxis from jellyfish sting

• **Cardiac Problem**
  – Long QT Syndrome (1 subtype provoked by swimming)
  – Myocardial infarction (older athlete)
  – Hypertrophic or other cardiomyopathy (younger athlete)

• **Heat Stroke** (rare)
Sudden Death in USA Triathlons 1985-2015

106 deaths and 11 resuscitated events.

41 had autopsy.

22 (54%) showed cardiac pathology.

Predominantly coronary artery disease but also cases of cardiomyopathy, coronary artery anomalies and electrical disorders.
Screening Strategies for Detecting Athletes with Potentially Serious Cardiac Disease
## Screening Athletes

<table>
<thead>
<tr>
<th>Condition</th>
<th>History</th>
<th>Examn</th>
<th>ECG</th>
<th>Echo</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCM</td>
<td>Pos/Neg</td>
<td>Pos in 25%</td>
<td>Positive</td>
<td>Pos</td>
</tr>
<tr>
<td>ARVC</td>
<td>Pos/Neg</td>
<td>Negative</td>
<td>Positive</td>
<td>Neg/Pos</td>
</tr>
<tr>
<td>WPW</td>
<td>Pos/Neg</td>
<td>Negative</td>
<td>Positive</td>
<td>Neg</td>
</tr>
<tr>
<td>LQTS</td>
<td>Pos/Neg</td>
<td>Negative</td>
<td>Positive</td>
<td>Neg</td>
</tr>
<tr>
<td>Marfan</td>
<td>Pos/Neg</td>
<td>Positive</td>
<td>Negative</td>
<td>Pos</td>
</tr>
<tr>
<td>CAA</td>
<td>Pos/Neg</td>
<td>Negative</td>
<td>Negative</td>
<td>Neg</td>
</tr>
<tr>
<td>Myocarditis</td>
<td>Pos/Neg</td>
<td>Pos/Neg</td>
<td>Pos/Neg</td>
<td>Pos</td>
</tr>
</tbody>
</table>

*INCREASING COST*
Medical history*

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, or otherwise) before age 50 years due to heart disease, in ≥1 relative
7. Disability from heart disease in a close relative <50 years of age
8. Specific knowledge of certain cardiac conditions in family members: hypertrophic or dilated cardiomyopathy, long-QT syndrome or other ion channelopathies, 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)§
357 consecutive athletes. Mean age $29 \pm 11$ years old.

92% Male. 69% competitive.
ECG in Patients with Cardiomyopathy

HCM
95%
Inferior and/or lateral TWI
ST segment depression
Pathological q waves

ARVC
40-50%
Anterior TWI (V2-V3/V4)
with isoelectric J point
Epsilon wave
Ventricular extra-systoles
Deaths in Triathlon
Cheap

Pragmatic

Poor sensitivity (<45%)

Most athletes asymptomatic

Most diseases are not associated with abnormal physical signs
Does Cardiac Screening Save Lives?
Screening Athletes: Impact on SCD

Corrado. JAMA 2006; 296:1593-1601

- 1979-2004

- 42,386 athletes (12-35 years)

- History, examination and 12-lead ECG

- 55 sudden cardiac deaths in screened athletes

- Death rates fell from 3.6/100,000/person years (pre-screening to 0.4/100,000/person years following screening.

- Reduction in deaths mainly from cardiomyopathies
TIME-TREND OF SUDDEN CARDIAC DEATH INCIDENCE IN ATHLETES VS NON-ATHLETES

Veneto Region of Italy 1979-2002

Corrado. JAMA 2006; 296:1593-1601
Comparison of U.S. and Italian Experiences With Sudden Cardiac Deaths in Young Competitive Athletes and Implications for Preparticipation Screening Strategies

Barry J. Maron, MD\textsuperscript{a,*}, Tammy S. Haas, RN\textsuperscript{a}, Joseph J. Doerer, BS\textsuperscript{a}, Paul D. Thompson, MD\textsuperscript{b}, and James S. Hodges, PhD\textsuperscript{c}

\textsuperscript{a}University of Minnesota, Minneapolis, Minnesota; \textsuperscript{b}University of Virginia, Charlottesville, Virginia; \textsuperscript{c}Boston University, Boston, Massachusetts

\textsuperscript{*}Corrado et al. JAMA 2006; 296: 1593-601
Maron et al. Am J Cardiol 2009; 104: 276-280
Concerns Relating to ECG Screening

Low incidence of sudden cardiac death

High number of false positives

Concerns relating to false negatives

Cost

Other issues
<table>
<thead>
<tr>
<th>Reference</th>
<th>Population</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHA (2007)</td>
<td>Competitive athletes (U.S.)</td>
<td>0.3%</td>
</tr>
<tr>
<td>Fuller (1997)</td>
<td>5,617 high school athletes (U.S)</td>
<td>0.4%</td>
</tr>
<tr>
<td>Corrado (2006)</td>
<td>42,386 athletes age 12-35 (Italy)</td>
<td>0.2%</td>
</tr>
<tr>
<td>Wilson (2008)</td>
<td>2,720 athletes /children age 10-17</td>
<td>0.3%</td>
</tr>
<tr>
<td>Bessem (2009)</td>
<td>428 athletes age 12-35 (Netherlands)</td>
<td>0.7%</td>
</tr>
<tr>
<td>Baggish (2010)</td>
<td>510 collegiate athletes</td>
<td>0.6%</td>
</tr>
<tr>
<td>Sheikh (2015)</td>
<td>5000 British elite athletes</td>
<td>0.3%</td>
</tr>
</tbody>
</table>
Concerns Relating to ECG Screening

Low incidence of sudden cardiac death

High number of false positives

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Cost

Other issues
ECG in Athletes

- VAGOTONIA
- Bradycardia
- AV block
- Repolarisation anomalies

- CHAMBER ENLARGEMENT
- Sokolow-Lyon Voltage criterion for LVH
- Incomplete RBBB
Right axis deviation

Incomplete RBBB

Sinus bradycardia 45 bpm

SV1 + RV6 > 3.5 mV = LVH
ECG in Athletes

INFLUENCING FACTORS

- Age
- Sex
- Ethnicity
- Type of sport
- Intensity of sport

VAGOTONIA

- Bradycardia
- AV block
- Repolarisation anomalies

CHAMBER ENLARGEMENT

- Sokolow-Lyon Voltage criterion for LVH
- Incomplete RBBB
# ECG Interpretation in an Athlete

## Table 1: Classification of abnormalities of the athlete’s electrocardiogram

<table>
<thead>
<tr>
<th>Group 1: common and training-related ECG changes</th>
<th>Group 2: uncommon and training-unrelated ECG changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinus bradycardia</td>
<td>T-wave inversion</td>
</tr>
<tr>
<td>First-degree AV block</td>
<td>ST-segment depression</td>
</tr>
<tr>
<td>Incomplete RBBB</td>
<td>Pathological Q-waves</td>
</tr>
<tr>
<td>Early repolarization</td>
<td>Left atrial enlargement</td>
</tr>
<tr>
<td>Isolated QRS voltage criteria for left ventricular hypertrophy</td>
<td>Left-axis deviation/left anterior hemiblock</td>
</tr>
<tr>
<td></td>
<td>Right-axis deviation/left posterior hemiblock</td>
</tr>
<tr>
<td></td>
<td>Right ventricular hypertrophy</td>
</tr>
<tr>
<td></td>
<td>Ventricular pre-excitation</td>
</tr>
<tr>
<td></td>
<td>Complete LBBB or RBBB</td>
</tr>
<tr>
<td></td>
<td>Long- or short-QT interval</td>
</tr>
<tr>
<td></td>
<td>Brugada-like early repolarization</td>
</tr>
</tbody>
</table>

RBBB, right bundle branch block; LBBB, left bundle branch block.
Evidence Based ECG Interpretation: 2004-2014

Prevalence and significance of an isolated long QT interval in elite athletes
Sanddeep Basavarajiah, Matthew Wilson², Gregory Whyte³, Ajay Shah¹, Elijah Behr⁴, and Sanjay Sharma⁵

Should axis deviation or atrial enlargement be categorised as abnormal in young athletes? The athlete's electrocardiogram: time for re-appraisal of markers of pathology
Sabihag Gati¹,², Nabeel Sheikh¹, Saqib Ghani¹, Abbas Zaidi¹, Mathew Wilson³, Hariharan Raju¹, Andrew Cox¹, Matt Reed¹, Michael Papadakis¹, and Sanjay Sharma¹,²,³

The prevalence, distribution, and clinical outcomes of electrocardiographic repolarization patterns in male athletes of African/Afro-Caribbean origin
Michael Papadakis¹,², Francois Carre³, Gaelle Kervio⁴, John Rawlins¹,², Vasilieos F. Panoulas², Navin Chandra¹,², Sandeep Basavarajiah⁵, Lorna Carby³, Tiago Fonseca², and Sanjay Sharma¹,²,³

Clinical significance of electrocardiographic right ventricular hypertrophy in athletes: comparison with arrhythmogenic right ventricular cardiomyopathy and pulmonary hypertension
Abbas Zaidi¹, Saqib Ghani³, Nabeel Sheikh¹, Sabihag Gati¹, Rachel Bastiaenen, Brendan Madden, Michael Papadakis², Hariharan Raju¹, Matthew Reed, Rajan Sharma, Elijah R. Behr, and Sanjay Sharma³
Sensitivity for all conditions: 60%
Sensitivity for serious conditions: 100%
Specificity: 94% in Caucasians, 84% in Black athletes
The Journey so far

2005

Cardiovascular pre-participation screening of young competitive athletes for prevention of sudden death: proposal for a common European protocol

Consensus Statement of the Study Group of Sport Cardiology of the Working Group of Cardiovascular Diseases in Exercise Physiology and Myocardial and Pericardial Disease of the European Society of Cardiology (ESC)

ESC REPORT

Published in European Heart Journal, 2010, 31, 243-259

doi:10.1093/eurheartj/ehp473

Recommendations for interpretation of 12-lead electrocardiogram in the athlete

Normal electrocardiographic findings: recognizing physiological adaptations in athletes

Jonathan A Drezner, Peter Fischbach, Victor Froelicher, et al.


doi:10.1136/bjsports-apr-2013-093117

2010

False positives

2013

2014

Comparison of Electrocardiographic Criteria for the Detection of Cardiac Abnormalities in Elite Black and White Athletes

Nabeel Sheikh, MRCP, Michael Papadakis, MRCP, Saqib Ghani, MRCP, Abhis Zaidi, MRCP; Sabitha Gati, MRCP; Paolo Adamo, MD; François Carré, PhD; Frédéric Schnell, PhD; Mathew Wilson, PhD; Paloma Avila, MD; William McKenna, MD, DSc, FESC; Sunjay Sharma, MD, FRCP, FESC (UK)
Normal ECG findings

- Voltage QRS criteria for LVH or RVH
- Incomplete RBBB
- Early repolarization/ST segment elevation
- ST elevation followed by T wave inversion in V1-V4 in black athletes
- T wave inversion in V1-V3 < age 16
- Sinus bradycardia or arrhythmia
- Ectopic atrial or junctional rhythm
- 1st degree AV block
- Mobitz type 1-2nd degree AV block

Borderline ECG findings

- Left or right atrial enlargement
- Left axis deviation
- Right axis deviation
- Complete RBBB

In isolation 2 or more

No further evaluation required
In asymptomatic athletes with no family history of inherited cardiac disease/SCD

Abnormal ECG findings

- T wave inversion beyond V2 in Caucasian adult athletes/beyond V4 in black athletes
- ST segment depression
- Pathological Q waves
- Complete LBBB
- IVCD ≥ 140ms
- Ventricular pre-excitation
- Long QT interval
- Profound sinus bradycardia <30bpm
- Profound 1st degree AV block ≥ 400ms
- Mobitz Type II 2nd degree AV block
- 3rd degree AV block
- ≥ 2 PVCs per 10 secs
- Atrial tacharrhythmias
- Ventricular tachyarrhythmias

Further evaluation required to investigate for CV disorders associated with SCD in athletes
Concerns

Low incidence of sudden cardiac death

High number of false positives

Concerns relating to false negatives

Cost

Other issues
Deaths Despite Screening with ECG

**False Negatives**
- Anomalous coronary arteries
- Premature atherosclerotic coronary disease
- Adrenergically driven ion channel disorders
- Incomplete expressions of cardiomyopathy

**Acquired conditions**
- Commotio cordis
- Myocarditis
- Electrolyte disorders
Cause of Cardiac Arrest in Marathons in the US

59 events

Information on 31 (23 dead and 8 survivors)

Athletes with HCM did not survive.
Concerns

Low incidence of sudden cardiac death

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Concerns relating to false negatives

Cost

Other issues
Conclusion

1. Sudden cardiac death in triathlon is rare.

2. Most triathlon deaths occur during swimming.

3. Screening with ECG will detect electrical faults and cardiomyopathies but will fail to identify most coronary artery abnormalities/disease.

4. Screening of athletes SHOULD take place in an EXPERT setting.
Pre-Participation Cardiac Screening in Athletes: What is the Evidence

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