Sudden Cardiac Death Risk in Athletes

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Objectives

To provide an overview of sudden cardiac death in athletes.

To discuss the effectiveness of accepted screening models to identify athletes at risk.

To discuss concerns regarding ECG screening.

To provide data on the impact of cardiopulmonary resuscitation in exercise related sudden cardiac arrest.
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 Cardiac Death in Young Athletes

- Incidence is approximately 1/50,000
- Mean age at death in athletes 23 years-old
- 40% deaths in athletes aged < 18 years old
- Males > females (9:1)
- Black athletes > white athletes
- 90% deaths during or immediately after exertion
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
Causes of Sudden Cardiac Death in Sport

Finnochiaro G, Sharma JACC 2016

357 consecutive athletes. Mean age 29 ± 11 years old.

92% Male. 69% competitive.
Triggers for Sudden Cardiac Death

- Dehydration
- Adrenergic surges
- Electrolyte imbalance
- Acid/base disturbance
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)§
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
33,735 competitive athletes were screened

- 22 athletes diagnosed with HCM
  - 3 identified on basis of family Hx (14%)
  - 16 identified by abnormal ECG
  - 2 identified on basis of murmur (9%)
Does Cardiac Screening Save Lives?
TIME-TREND OF SUDDEN CARDIAC DEATH INCIDENCE IN ATHLETES VS NON-ATHLETES
Veneto Region of Italy 1979-2002

42,386 athletes (12-35 years)

55 deaths in athletes

Corrado. JAMA 2006; 296:1593-1601
Mandatory Electrocardiographic Screening of Athletes to Reduce Their Risk for Sudden Death
Proven Fact or Wishful Thinking?

Arie Steinvil, MD,* Tamar Chundadze, MD,* David Zeltser, MD,* Ori Rogowski, MD,*
Amir Halkin, MD;† Yair Galily, PhD;‡ Haim Perluk, MD;§ Sami Viskin, MD†

Annual Incidence of Sudden Cardiac Death Expressed per 100,000 Person-Years in the 3 Studies Evaluating the Effects of Screening on the Mortality of Athletes Over Time

[Graph showing data for Italian Sport Law, Israel Sport Law, Veneto (Italy), and Minnesota (USA) from 1979-80 to 2007-08]
Concerns Regarding ECG Screening
Concerns Relating to ECG Screening

Low incidence of sudden cardiac death

High number of false positives

Cost

Concerns relating to false negatives
<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

Cost

Concerns relating to false negatives
ECG in Athletes

VAGOTONIA
Bradycardia
AV block
Repolarisation anomalies

CHAMBER ENLARGEMENT
Sokolow-Lyon Voltage criterion for LVH
Incomplete RBBB
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 abnormalities in the athlete

- Sinus bradycardia
- First degree AV block
- Notched QRS in V1 or incomplete RBBB
- Early repolarization
- Isolated QRS voltage criteria for left ventricular hypertrophy

Group 1: common (up to 80%)

Group 2: uncommon (< 5%)

- T-wave inversion
- ST-segment depression
- Pathological Q waves
- Left atrial enlargement
- Left axis deviation/left anterior hemiblock
- Right axis deviation/left posterior hemiblock
- Right ventricular hypertrophy
- Complete LBBB or RBBB
- Long or short QT interval
- Brugada-like early repolarization
- Ventricular arrhythmias
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, Vasileios F. Panoulas², Navin Chandra¹,², Sandeep Basavarajaiah², Lorna Carby², Tiago Fonseca², and Sanjay Sharma¹,²*

¹St. George’s University of London, Cranmer Terrace, SW17 0RE, London, UK; ²University Hospital Lewisham, London, UK; ³French Institute of Health and Medical Research (INSERM), U452, Rennes, F-35000, France; and ⁴French Institutes of Health and Medical Research (INSERM), CIC-IT 804, Rennes, F-35000, France

Received 7 January 2011; revised 15 February 2011; accepted 25 March 2011
Prevalence of Abnormal ECG Patterns in Athletes

Observed in 23% of Black Athletes
- majority in anterior leads
TWI in a Black Athletes

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vent. rate</td>
<td>64 bpm</td>
</tr>
<tr>
<td>PR interval</td>
<td>160 ms</td>
</tr>
<tr>
<td>QRS duration</td>
<td>96 ms</td>
</tr>
<tr>
<td>QT/QTc</td>
<td>468/482 ms</td>
</tr>
<tr>
<td>P-R-T axes</td>
<td>41 55 4</td>
</tr>
</tbody>
</table>

12.4%

Technician: SW

Referred by: OP, SS2

Unconfirmed

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**ECG Tracing**

- aVR, V1, V4, V5, aVL, V2, V3, aVF, aV, V4, V5, V6
ECG abnormalities in the athlete

(Group 1) common (up to 80%)
- Sinus bradycardia
- First degree AV block
- Notched QRS in V1 or incomplete RBBB
- Early repolarization
- Isolated QRS voltage criteria for left ventricular hypertrophy

(Group 2) Uncommon (< 5%)
- T-wave inversion
- ST-segment depression
- Pathological Q waves
- Left atrial enlargement
- Left axis deviation/left anterior hemiblock
- Right axis deviation/left posterior hemiblock
- Right ventricular hypertrophy
- Complete LBBB or RBBB
- Long or short QT interval
- Brugada-like early repolarization
- Ventricular arrhythmias
Differences from the ESC 2010

Included in the normal category:

T wave inversion in V1-V4 in black athletes.

T wave inversion in V1-V2 in all athletes.

QTc < 320 for short QT

QTc > 470 M and < 480 F for long QT

Criteria for RVH also include RAD
Evidence Based ECG Interpretation: 2004-2014

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

The prevalence, distribution, and clinical outcomes of electrocardiographic repolarization patterns in male athletes of African/Afro-Caribbean origin
Michael Papadakis¹², Francois Carre³, Gaelle Kervio⁴, John Rawlins¹², Vasileios F. Panoulas³, Navin Chandra¹², Sandeep Basavarajiah¹, Lorna Carby³, Tiago Fonseca³, and Sanjay Sharma¹²

Clinical significance of electrocardiographic right ventricular hypertrophy in athletes: comparison with arrhythmogenic right ventricular cardiomyopathy and pulmonary hypertension
Abbas Zaidi, Saqib Ghani, Nabeel Sheikh, Sabiha Gati, Rachel Bastiaenan, Brendan Madden, Michael Papadakis, Harirhan Raju, Matthew Reed, Rajan Sharma, Elijah R. Behr, and Sanjay Sharma

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
Sabiha Gati¹,², Nabeel Sheikh¹, Saqib Ghani¹, Abbas Zaidi¹, Mathew Wilson³, Harirhan Raju¹, Andrew Cox¹, Matt Reed¹, Michael Papadakis¹, and Sanjay Sharma¹,²

¹St George’s University of London, Cranmer Terrace, SW17 0RE, London SE15 8RS, UK; ²University Hospital Lewisham, London, UK; ³Aspetar, Department of Sports Medicine, Qatar Orthopaedic and Sports Medicine Hospital, Doha, Qatar

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[Additional articles listed]
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; Abbas Zaidi, MRCP; Sabiha Gati, MRCP; Paolo Adami, MD; François Carré, PhD; Frédéric Schnell, PhD; Mathew Wilson, PhD; Paloma Avila, MD; William McKenna, MD, DSc, FESC; Sanjay Sharma, MD, FRCP, FESC (UK)

Sensitivity for all conditions: 60%
Sensitivity for serious conditions: 100%
Specificity: 94% in Caucasians, 84% in Black athletes

A

Refined Criteria Training Related Normal Variants
Not Warranting Further Investigation*
- Sinus bradycardia
- First-degree AV block
- Incomplete RBBB
- Early repolarisation
- Isolated QRS voltage criteria for LVH

Refined Criteria Borderline Variants
Potentially Warranting Further Investigation
- Left atrial enlargement
- Right atrial enlargement
- Left axis deviation
- Right axis deviation
- RVH
- TWI up to V4 in BAs†

Refined Criteria Training Unrelated Changes
Warranting Further Investigation
- ST-segment depression
- Pathological Q-waves
- Ventricular pre-excitation
- TWI beyond V1 in WAs beyond V4 in BAs
- Complete LBBB or RBBB
- QTc ≥470 msec in males
- ≥480 msec in females
- Brugada-like ER
- Atrial or ventricular arrhythmias

If present in ISOLATION*
If TWO OR MORE present
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

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 <30 bpm
- Profound 1st degree AV block ≥ 400 ms
- Mobitz Type II 2nd degree AV block
- 3rd degree A V block
- ≥ 2 PVCs per 10 secs
- Atrial tacharrhythmias
- Ventricular tachyarrhythmias

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

2 or more
- Further evaluation required to investigate for CV disorders associated with SCD in athletes
Overlap With Disease

- Repolarisation changes and increased heart size
- Juvenile EKG pattern
- Long standing endurance athlete
- Anabolic drug abuse
- Black athletes
- Cardiomyopathy

Overlap With Disease
Concerns

Low incidence of sudden cardiac death

High number of false positives

Concerns relating to false negatives
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
Alternative Strategies
Exercise related cardiac arrest

Mean age 46.1 ± 15.8. 93% Male.

Survival 15%
Exercise related cardiac arrest
Incidence in the general population  Netherlands (2006 – 2009)

Mean age  58.8 ± 13.6.         95% Male.

Survival 45%
<table>
<thead>
<tr>
<th>Country</th>
<th>Netherlands</th>
<th>France</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>58.8 ± 13.6</td>
<td>46.1 ± 15.8</td>
</tr>
<tr>
<td>Success rate</td>
<td>45%</td>
<td>15%</td>
</tr>
<tr>
<td>Men</td>
<td>93%</td>
<td>95%</td>
</tr>
<tr>
<td>Bystander witnessed arrest</td>
<td>89%</td>
<td>94%</td>
</tr>
<tr>
<td>Bystander CPR</td>
<td>87%</td>
<td>31%</td>
</tr>
<tr>
<td>AED use</td>
<td>36%</td>
<td>1%</td>
</tr>
<tr>
<td>Shockable initial rhythm</td>
<td>80%</td>
<td>47%</td>
</tr>
<tr>
<td>Time to first shock (min)</td>
<td>9.8 (6.4 – 12.5)</td>
<td>12.5 (10.5 – 15.5)</td>
</tr>
</tbody>
</table>
Cardiac Arrest during Long-Distance Running Races

10.9 million runs

59 deaths. 29% survival death rate

<table>
<thead>
<tr>
<th>FACTOR</th>
<th>ODDS RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>By stander CPR</td>
<td>3.73 CI 2.19-6.39</td>
</tr>
<tr>
<td>Time of collapse to CPR</td>
<td>1.32 CI 1.08-1.61</td>
</tr>
<tr>
<td>Initial use of AED</td>
<td>3.71 CI 2.07-6.64</td>
</tr>
</tbody>
</table>

36 cases of SCA

Prompt CPR 94%
AED shock 83%

14 (high school)
Mean age 16

22 older non students
Mean age 57

64% survived to hospital discharge in each group
Higher survival rates may have been to the onsite AED (79%) and smaller number of cases of hypertrophic cardiomyopathy (21%)
Delay Intervals

• Mean time from collapse to CPR

1.5 Minutes

• Mean time from SCA to first shock

3.6 Minutes
The Emergency Response Plan

Personnel

Communication system

Location of the AED

Practice and review of emergency response plan
Conclusions

• Sudden cardiac death is rare in young athletes

• The ECG is effective in detecting athletes with hypertrophic cardiomyopathy.

• Contemporary criteria are associated with a significantly lower false positive rate (3-5%) in white athletes.

• A normal ECG does not confer protection from SCD.
Sudden Cardiac Death Risk in Athletes

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