Sudden Cardiac Death in Athletes
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Medical Director for London Marathon
Lead cardiologist for 2012 Olympics
Objectives

To discuss the magnitude of the problem of and causes of sudden cardiac death

To provide information in differentiating physiologic adaptation from cardiac pathology.

To discuss preventative strategies to reduce the risk sudden cardiac death during sport.
<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</td>
<td>13-17</td>
<td>12 years</td>
<td>0.5/100,000/yr</td>
</tr>
<tr>
<td>athletes</td>
<td></td>
<td></td>
<td></td>
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<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>
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</table>
Sudden Cardiac Death in Senior Athletes
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

• More common in males than females (9:1)

• 90% deaths during or immediately after exertion
Causes of SCD in Sport

- Congenital + Anatomic: 37%
- Cardiomyopathies: 14%
- Arrhythmias: 9%
- Infectious: 4%
- Degenerative: 1%
- Acquired: 35%
- Undetermined: 1%
- "Normal heart": 14%
Relative Risk of SCD

Corrado D JACC 2003
Triggers for Sudden Cardiac Death

- Dehydration
- Adrenergic surges
- Acid/base disturbance
- Electrolyte imbalance
Clinical Manifestations

Asymptomatic
Chest pain
Dyspnoea
Palpitation
Exertional dizziness
Syncope
Epilepsy
Sudden death

Family History
Obvious hereditary cardiac disorder
Sudden cardiac death
Epilepsy
Unexplained drowning
Road traffic accidents
Sudden Cardiac Death in Sport

Hypertrophic Cardiomyopathy

Arrhythmogenic right ventricular cardiomyopathy
Hypertrophic Cardiomyopathy
Failure to augment SV

Low peak oxygen consumption

Failure to augment SV

Low peak oxygen consumption
Natural History of HCM

- **Asymptomatic Mild LVH**
- **Development of LVH**
  - Sudden death
- **Severe symptoms**
- **Progressive symptoms**
- **AF, CVA or Heart Failure**
- **Death due to natural causes**
- **Normal echo but abnormal ECG**
- **Development of LVH and symptoms**

**Age Groups**:
- **Age 0-12**
- **Age 12-35**
- **Age 35-60**
- **Age 60-85**

[Cardiac Risk in the Young Centre for Sports Cardiology]
Diagnosis
The ECG in Hypertrophic Cardiomyopathy

• No specific ECG markers for diagnosis of HCM.
• Abnormal in approximately 95%.
• Large QRS complexes, pathologic q waves, ST segment and T wave abnormalities.
• May be the only clinical expression of the disease
• Voltage criteria for LVH in isolation is rare.
Arrhythmogenic Right Ventricular Cardiomyopathy
Pathophysiology of ARVC
Natural History of ARVC

Not fully understood. Can occur at any age

4 distinct phases

1. Early concealed phase
2. Overt electrical disorder
3. Progression of myocardial disease
4. Significant left ventricular involvement

Advancing Disease

Cardiac Risk in the Young Centre for Sports Cardiology
Coronary arteries and aorta
Sudden Death in Athletes: The British Experience

UK SCD, n=118, age range 7-59 yr

- Normal: 23%
- LVH: 23%
- LVH w/ IF: 8%
- Myocarditis: 3%
- Aortic Valve: 2%
- Other: 4%
- ARVC: 14%
- HCM: 11%
- IF: 6%
- A CA: 2%
- Atheroma: 3%
- Atheroma: 3%
Sudden Cardiac Death with a Normal Heart

- LQTS
- Brugada
- WPW
DEFECTIVE ION CHANNEL

ADRENERGIC SURGE

LONG QT INTERVAL

PREDILECTION TO POLYMORPHIC VT/VF

Intense emotion
-
Loud stimuli
-
Fear
-
Swimming
-
Performance enhancing drugs

ADRENERGIC SURGE

Electrocardiogram images showing long QT interval and polymorphic VT/VF.
Brugada Syndrome

Bradycardia  Hyperpyrexia
Diagnosing Athletes with Cardiac Disease
Athlete’s Heart

**ELECTRICAL**
- Bradycardia
- Repolarisation anomalies
- Voltage criteria for chamber enlargement

**STRUCTURAL**
- Increased wall thickness
- Increased cavity size

**FUNCTIONAL**
- Enhanced diastolic filling
- Augmentation of stroke volume
The Young Athlete’s Heart

10% increase in LV and RV cavity.

10-20% increase in left ventricular wall thickness
Electrical and Structural Adaptation in the Athlete’s Heart

ECG
Bradycardia
AV block
Voltage criteria for chamber enlargement
Repolarisation anomalies

CARDIAC IMAGING
Increased cavity size
Increased wall thickness

Physiology Pathology
Overlap With Disease

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

Cardiac Risk in the Young Centre for Sports Cardiology
Athlete’s ECG

Caucasian athlete

Athlete of African/Afro-Caribbean descent
The Overlap With Cardiomyopathy in Black Athletes

4% + 13% = ?HCM

14.3% + 28% = ?ARVC

5% + 3% = ?
Prevention of Sudden Cardiac Death
Management of Athletes with Cardiac Disease

General:

Abstinence from moderate to intensive exercise

Specific:

Survivor of SCD  ICD
Long QT/CPVT  Beta blockers
WPW  ablation of accessory
Marfan  pathway
Anomalous coronaries  surgery

Cardiac Risk in the Young Centre for Sports Cardiology
Arguments For and Against Screening

**For**
- Highly visible events
- Loss of numerous years of life
- Association between exercise and sudden death
- Acceptable interventions to prevent fatalities

**Against**
- Sudden deaths in athletes uncommon; 1 in 50,000
- Rare disorders. Diverse pathology
- Elaborate screening programmes not cost effective
- Risk of false positives
young competitive athletes

family and personal history, physical examination, 12-lead ECG

- negative findings: eligible for competition
  - no evidence of cardiovascular disease
- positive findings: further examinations (echo, stress test, 24-h Holter, cardiac MRI, angio/EMB, EPS)
  - diagnosis of cardiovascular disease: management according to established protocols
ECG in Patients with Cardiomyopathy

HCM 95%

ARVC 80%
TIME-TREND OF SUDDEN CARDIAC DEATH INCIDENCE IN ATHLETES VS NON-ATHLETES

Veneto Region of Italy 1979-2002
Concerns

Low incidence of sudden cardiac death

High number of false positives

Concerns relating to false negatives

Cost

Other issues
# Prevalence of Young Athletes with Conditions Predisposing to SCD

<table>
<thead>
<tr>
<th>Ref:</th>
<th>Population</th>
<th>Prevalence</th>
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<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 (U.S.)</td>
<td>0.6%</td>
</tr>
</tbody>
</table>
Concerns

Low incidence of sudden cardiac death

High number of false positives

Concerns relating to false negatives

Cost

Other issues
High False Positive Rate

- False positive rate 10%
- False positive rate 16.9%
- False positive rate 17.3%

The Seattle Criteria increase the specificity of preparticipation ECG screening among elite athletes.
TWI in a Black Athletes

12.4%
Evidence Based ECG Interpretation:
2004-2014

The prevalence, distribution, and clinical outcomes of electrocardiographic repolarization patterns in male athletes of African/Afro-Caribbean origin

Michael Papadakis, Francois Carre, Gaelee Kervio, John Rawlins, Vasileios F. Panoulas, Navin Chandra, Sandeep Basavarajaiah, Lorna Carby, Tiago Fonseca, 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

Sabih Gati, Nabeel Sheikh, Saqib Ghani, Abbas Zaidi, Mathew Wilson, Harihans Raju, Andrew Cox, Matt Reed, Michael Papadakis, and Sanjay Sharma

Prevalence and significance of an isolated long QT interval in elite athletes

Sandeep Basavarajaiah, Matthew Wilson, Gregory Whyte, Ajay Shah, Elijah Behr, and Sanjay Sharma

Clinical significance of electrocardiographic right ventricular hypertrophy in athletes: comparison with arrhythmogenic right ventricular cardiomyopathy and pulmonary hypertension

Abbas Zaidi, Saqib Ghani, Nabeel Sheikh, Sabih Gati, Rachel Bastiaenen, Brendan Madden, Michael Papadakis, Harihans Raju, Matthew Reed, Rajan Sharma, Elijah R. Behr, and Sanjay Sharma
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 Adamo, 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
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
- Incomplete expressions of cardiomyopathy and ion channel disease

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%
# Exercise related cardiac arrest

<table>
<thead>
<tr>
<th>Country</th>
<th>Netherlands</th>
<th>France</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age, years</strong></td>
<td>58.8 ± 13.6</td>
<td>46.1 ± 15.8</td>
</tr>
<tr>
<td><strong>Success rate</strong></td>
<td>45%</td>
<td>15%</td>
</tr>
<tr>
<td><strong>Men</strong></td>
<td>93%</td>
<td>95%</td>
</tr>
<tr>
<td><strong>Bystander witnessed arrest</strong></td>
<td>89%</td>
<td>94%</td>
</tr>
<tr>
<td><strong>Bystander CPR</strong></td>
<td>87%</td>
<td>31%</td>
</tr>
<tr>
<td><strong>AED use</strong></td>
<td>36%</td>
<td>1%</td>
</tr>
<tr>
<td><strong>Shockable initial rhythm</strong></td>
<td>80%</td>
<td>47%</td>
</tr>
<tr>
<td><strong>Time to first shock (min)</strong></td>
<td>9.8 (6.4 – 12.5)</td>
<td>12.5 (10.5 – 15.5)</td>
</tr>
</tbody>
</table>
Major regional disparities in outcomes after sudden cardiac arrest during sports

Eloi Marijon\textsuperscript{1,2,3,4*}, Wulfran Bougouin\textsuperscript{1,2,3,4}, David S. Celermaier\textsuperscript{5}, Marie-Cécile Perier\textsuperscript{1,2},

Overall 16\% survival after sports-related cardiac arrest.

But 50\% in regions with high rates of bystander resuscitation
Cardiac Arrest during Long-Distance Running Races

10.9 million runs

59 deaths.  29 % survival death rate

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<th>FACTOR</th>
<th>ODDS RATIO</th>
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<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>

Kim et al NEJM 2012
Cardiac Arrest during Long-Distance Running Races

Survivor 29%

Death 71%

CPR Time taken for Emergency Arrival (mins)

VF

HCM

Kim et al NEJM 2012

100% 3.3 88% 0%

40% 7.7 35% 66%

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

Emergency response plan
Premier League March 2012
Conclusions

• Sudden cardiac death in young athletes is rare.

• Exercise is a trigger for SCD in predisposed athletes.

• The diagnosis of cardiac pathology is challenging in some athletes.

• Pre-participation screening with ECG identifies athletes with cardiomyopathy.

• Early CPR and AEDs save lives in sport.
Sudden Cardiac Death in Athletes

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