The time you won your town the race
We chaired you through the market-place;
Man and boy stood cheering by,
And home we brought you shoulder high.

To-day the road all runners come,
Shoulder-high we bring you home,
And set you at your threshold down,
Townsmen of a stiller town.”

— To An Athlete Dying Young
Alfred Edward Housman, 1895

Cardiovascular Diseases (69%)

Trauma (18%)

Heat Stroke (1%)

Drugs (2%)

Other Non-CV (4%)

Commotio Cordis (6%)

Cardiovascular Diseases (69%)
**Sudden Death in Young Athletes**

- HCM (36%)
- Indeterminate LVH - possible HCM (8%)
- Coronary artery anomalies (17%)
- Myocarditis (6%)
- ARVC (4%)
- MVP (4%)
- Tunneled LAD (3%)
- CAD (3%)
- AS (3%)
- Dilated C-M (2%)
- Sarcoidosis (1%)
- Aortic rupture (2%)
- Ion channelopathies
- Other congenital HD
- Other (3%)
- Normal heart (3%)

**Diurnal Distribution of Sudden Death in Young Athletes**

![Graph showing diurnal distribution with peak times]
Highest 2005/2006 = 76 / y
Last 6 years = avg. 66 / y

Diseases not reliably detectable by history / physical / ECG = 30% (of ~ 75 / y)

Therefore, ECG preparticipation screening would identify = 50 athletes / y
Obstacles To Screening

- Denominator
- Numerator
- Event Infrequency

Participation Rates For Competitive Athletes in U.S.

- Millions of Athletes
- High School: 1
- College: 2
- Pro: 3

Athletes of the World

- SUDDEN DEATH IN ATHLETES
- HCM=35%
- HCM=5.2%

ATHLETES OF THE WORLD
Frequency Estimates for Sudden Cardiac Death In Athletes

Young (high school / college) : ~1 : 200,000
Older (runners, including marathon) : ~1 : 15,000 / ~1 : 50,000

Importance of Sudden Cardiac Death in Athletes

• Commands our attention — a riveting issue
• Competitive athletes appear to be the healthiest segment of society
• Symbolic issue
• Media driven

Preparticipation Athletic Screening USA vs. Italy

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<td>Basis</td>
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<tr>
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<td>no precedent</td>
<td>civil / criminal</td>
</tr>
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</table>
AHA Consensus Panel Recommendations for Preparticipation Athletic Screening

**Family History:**
1. Premature sudden cardiac death
2. Heart disease in surviving relatives

**Personal History:**
3. Heart murmur
4. Systemic hypertension
5. Fatigue
6. Syncope/near-syncope
7. Excessive/unexplained exertional dyspnea
8. Exertional chest pain

**Physical examination:**
9. Heart murmur (supine/standing)
10. Femoral arterial pulses
11. Stigmata of Marfan syndrome
12. Brachial blood pressure measurement (sitting)

**Sudden Death in Young Athletes-Veneto**

- ARVC (36%)
- CAD (20%)
- Tunneled LAD (2%)

Other congenital HD (1%)
Aortic rupture (1%)
Sarcoidosis (1%)
Dilated C-M (1%)
AS (2%)
Ion channelopathies (2%)
Takotsubo/LV remodeling (1%)
Ischemic LV infarct - possible HCM (2%)
Normal heart (3%)

**Italy**

ARVC (1%)
Coronary artery anomalies (5%)
HCM (4%)
MVP (3%)
Tunneled LAD (2%)
CAD (20%)
AS (2%)
HCM

USA

Indeterminate LVH - possible HCM (8%)
Coronary artery anomalies (17%)
Myocarditis (6%)
ARVC (4%)
MVP (4%)
Tunneled LAD (3%)
CAD (3%)
AS (3%)
Dilated C-M (2%)
Sarcoidosis (1%)
Aortic rupture (2%)
Ion channelopathies
Other congenital HD
Other (3%)
Normal heart (3%)

Sudden Death in Young Athletes

HCM (36%)

Center for Sports Medicine
Padua, Italy (1979-96)

33,735 Athletes screened

(0.07%) 22 HCM By Echo

3 Family History 5 PVC 2 Murmur 16 Abnormal ECG
Comparison of Cardiovascular Disease Mortality in Young U.S. and Italian Competitive Athletes

<table>
<thead>
<tr>
<th></th>
<th>Veneto</th>
<th>Minnesota</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population (million)</td>
<td>4.38</td>
<td>4.66</td>
</tr>
<tr>
<td>Race (white)</td>
<td>90%</td>
<td>90%</td>
</tr>
<tr>
<td>Size (km²)</td>
<td>26,000</td>
<td>296,000</td>
</tr>
<tr>
<td>Years screening</td>
<td>1979-2004</td>
<td>1985-2007</td>
</tr>
<tr>
<td>Total years</td>
<td>26</td>
<td>23</td>
</tr>
<tr>
<td>Total person-y</td>
<td>2.93 M</td>
<td>2.07 M</td>
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<tr>
<td>Sudden CV deaths</td>
<td>55</td>
<td>22</td>
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<tr>
<td>Age at death (mean)</td>
<td>23 y</td>
<td>17 y</td>
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<tr>
<td>Deaths 1993-2004</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>Deaths 2001-2004</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>
Comparison of Cardiovascular Disease Mortality in Young U.S. (Minnesota) & Italian (Veneto) Competitive Athletes

Obstacles to the Italian Screening Initiative in the U.S.

- Too many athletes; but, why not study all young people?
- Very uncommon events
- Too many false positives; also false negatives
- Cost / efficacy considerations
- Too many lawyers; liability considerations
- Would require mandatory system, based in law, in which physicians would be deciders and enforcers
  - No one to perform examinations / interpret ECGs
**Bethesda Conference # 36**

**Classification**
- Sports (#8)

**Consensus Panels**
- #2 Congenital
- #3 Valve
- #4 HCM
- #5 Other C-M
- #6 Arrhythmias
- #7 MVP
- #8 Myocarditis
- #9 CAD
- #10 HTN
- #11 Drugs
- #12 AED
- #13 Commotio
- #14 Legal

**Bethesda Conference # 36**

**Recommendations**

*Athletes with the unequivocal diagnosis of hypertrophic cardiomyopathy should not participate in most competitive sports, with the possible exception of those of low intensity. This recommendation includes those athletes with or without symptoms and with or without left ventricular outflow obstruction.*
Diseases not reliably detectable by history / physical / ECG = 30% (of ~ 75/y)

Therefore, ECG preparticipation screening would identify = 50 athletes/y

Figure. Annual incidence rates of sudden cardiovascular death in screened competitive athletes and unscreened nonathletes aged 12 to 35 years in the Veneto region of Italy (1979-2004)

Comparison of Cardiovascular Disease Mortality in Young U.S. (Minnesota) & Italian (Veneto) Competitive Athletes
Cardiovascular Diseases (69%)

Trauma (18%)

Commotio Cordis (6%)

Other Non-CV (4%)

Heat Stroke (3%)

Drugs (2%)

Sudden Death In Young Athletes
Comparison of State History and Physical Examination Preparticipation Screening Forms, 1997 vs. 2005

<table>
<thead>
<tr>
<th>No. Recommended AHA Screening Items</th>
<th>% of States</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td></td>
</tr>
</tbody>
</table>

Comparison of Approved Examiners for Preparticipation Screening, 1997 vs. 2005

<table>
<thead>
<tr>
<th>Percentage of States</th>
<th>M.D. / D.O.</th>
<th>R.N.</th>
<th>P.A.</th>
<th>Chiropractor</th>
<th>Others</th>
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</thead>
<tbody>
<tr>
<td>1997</td>
<td>20</td>
<td>20</td>
<td>9</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>45</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Designated Examiners
HCM and Race

Competitive Athletes: HCM-related Sudden Death (n=102)
- White (45%)
- African-American (55%)

Hospital – Based HCM Patients (n=1,986)
- White (92%)
- African-American (5%)

Cardiovascular Diseases (69%)
- Trauma (16%)
- Heat Stroke (3%)
- Drugs (2%)
- Other Non-CV (4%)
- Commotion Cordis (6%)

Sudden Death In Young Athletes

Highest 2005/2006 = 76 / y
U.S. Sudden Death in Young Competitive Athletes Registry, 1980-2006
(n=1,866)

### Last 6 years = avg. 66 / y

### Diseases not reliably detectable by history / physical / ECG = 30% (of ~75/y)

Therefore, ECG preparticipation screening would identify = 50 athletes/y
Preparticipation Athletic Screening

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<tr>
<td>Examiners</td>
<td>M.D. + accredited non-M.D.</td>
<td>accredited non-M.D.</td>
</tr>
<tr>
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ITALY

ARVC

Figure. Annual Incidence Rates of Sudden Cardiac Death in Screened Competitive Athletes and Unscreened Nonathletes Aged 12 to 35 Years in the Veneto Region of Italy (1979-2004)

Corrado D et al. JAMA 2004
Comparison of Cardiovascular Disease Mortality in Young U.S. (Minnesota) & Italian (Veneto) Competitive Athletes

Pediatric cardiologists in the U.S.  = 1,521

# of athletes to be screened  = 12 million

# of exams/ECGs to be performed  = 7,890 / year
= 658 / month
= 150 / week
Comмотіо Кордис:

Незаповнене смерть, не-пронизуючий і грубо невинний удар грудної клітки
Age at Which 154 Commotio Cordis Events Occurred

Blunt Chest Blow and Cardiac Arrest : Sports
### Commotio Cordis Events Unassociated With Sports

<table>
<thead>
<tr>
<th>Activity</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic (hollow) toy bat</td>
<td>1</td>
</tr>
<tr>
<td>Plastic sledding saucer</td>
<td>1</td>
</tr>
<tr>
<td>Playful (“shadow”) boxing</td>
<td>6</td>
</tr>
<tr>
<td>Hiccups remedy (by friend)</td>
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<tr>
<td>Head of pet dog (Collie)</td>
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</tr>
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<td>Snowball</td>
<td>1</td>
</tr>
<tr>
<td>Tennis ball (coin filled)</td>
<td>1</td>
</tr>
<tr>
<td>Swing carriage</td>
<td>1</td>
</tr>
</tbody>
</table>

### Commotio Cordis: Protection

- **Everyday Activities**: (never strike the chest)
- **Sports**: Chest protectors & Safety-balls
- **AED**: Education
Commotio Cordis: Protection

Everyday Activities → Education (never strike the chest)

Sports → AED

Chest protectors & Safety-balls
Robert Gordon

- Father age 35
- Inflicted 2 modest chest blows during tutorial session
- 11-year old son collapsed immediately
- Autopsy diagnosis: commotio cordis
- Father charged with first degree murder
- Admitted to psychiatric facility
- Plea bargained involuntary manslaughter
- Judge imposed 6-18 year sentence
Commotio Cordis: Determinants

- Location
- Timing
- Force
- Compliant chest wall
Lacrosse Chest Wall Protection

Brine Pro  DeBeer Icon  Brine GBP

STX  Warrior

Incidence of Ventricular Fibrillation
### Direct Comparison of Death Rates in Veneto & Minnesota, 1993-2004

<table>
<thead>
<tr>
<th></th>
<th>Veneto</th>
<th>Minnesota</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. deaths</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>Person-y</td>
<td>1,379,000</td>
<td>1,179,690</td>
</tr>
<tr>
<td>Death rate/person-y</td>
<td>0.87</td>
<td>0.93</td>
</tr>
</tbody>
</table>

\[ \text{p} = 0.87 \]

### History
- Syncope
- Family history of SD

### Physical Exam
- Heart murmur

### ECG/ECHO

### Nonobstructive HCM
Can “Athletic Field Deaths” Be Prevented?

35 y – Brother SD (age 39)
36 y – ICD
40 y – Generator replaced
41 y – Appropriate shock #1
50 y – Appropriate shock #2
52 y – Present

Preparticipation Screening: Is It Worth It?

• Screening is already customary practice for most high school and college athletes
• Improved screening on national basis would mean many more new diagnoses
• 5% of new HCM diagnoses are via screening
Obstacles to the Italian Screening Initiative in the U.S.

- Too many athletes
- Very uncommon events
- **No one to perform examination / ECGs**
- No one to interpret tests
- Too many false positives
- Cost / efficacy considerations and BUSH
- Too many lawyers: liability considerations
Sudden Death in Young Athletes in U.S.

One athlete dies q 3 days ...  
One athlete w/ HCM dies q 2 wks

Unusual Patterns of LVH
- LV Cavity < 45mm
- LV Cavity > 55mm
- LA Enlargement
- Bizarre ECG Patterns
- Abnormal LV Filling
- Female Gender
- LV Thickness w/ Decondition
- Familial HCM Mutation
- >50ml / kg / min max VO2

“Gray Zone”
LV Wall Thickness (13-15mm)

ICD - HCM: Appropriate Shocks: 2007

Follow-up = 3.7 years
505
- 102
- 11% 
2° prevention

5.4% / yr
ICD Discharge Rate
- 4%
1° prevention

505
162
Appropriate Shocks (20%)
Consequences of Medical Evaluations in Young Competitive Athletes Who Died Suddenly

Standard screening Cardiovascular evaluation

115

130

Preparticipation evaluation

Suspicion of C-V disease

Correct diagnosis

Disqualified

No evaluation

Survival Data in Commotio Cordis and Relation to Promptness of CPR by Bystanders

Cardiac Rhythm Restored

Unsuccessful Died

Coma Died

Survived

No CPR

Unsuccessful Died

Survived

(<3 min.)

(>3 min.)

Unresolved Cases

Miscellaneous

Cardiovascular

Commotio Cordis

Drugs

Pulmonary

Other*

Non-exertional Exertional

Cardiovascular event

Considered CV event (no precise diagnosis)

Confirmed CV event

Unconfirmed

Heart Rupture

Other**

HCM CA

Anomalies

Possible HCM

‡ Myocarditis

ARVC Ion Channel

MVP

LAD

Bridge CAD

Aortic Rupture AS

Dilated CM WPW
Pediatric cardiologists in the U.S. = 1,521

# of athletes to be screened = 12 million

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   = 658 / month
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Trauma (16%)

Commotio Cordis (6%)

Other Non-CV (4%)

Heat Stroke (3%)

Diseases (2%)

Coronary Anomalies (17%)

Possible HCM* (8%)

Sudden Death in Young Athletes

U.S. Sudden Death in Young Competitive Athletes Registry, 1980-2006 (n=1,886)

Highest 2005/2006 = 76 / y

Diseases not reliably detectable by history / physical / ECG = 30% (of ~ 75/y)

Therefore, ECG preparticipation screening would identify = 50 athletes/y
Obstacles To Screening

- Denominator
- Numerator
- Event Infrequency

Participation Rates For Competitive Athletes in U.S.

ATHLETES OF THE WORLD

S U D D E N  D E A T H  I N  A T H L E T E S

ATHLETES OF THE WORLD

SUDDEN DEATH IN ATHLETES
Frequency Estimates for Sudden Cardiac Death In Athletes

Young (high school / college): ~1 : 200,000

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Importance of Sudden Cardiac Death in Athletes

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Comparison of Cardiovascular Disease Mortality in Young U.S. (Minnesota) & Italian (Veneto) Competitive Athletes
**Obstacles to the National Mandatory Italian Screening Initiative in the U.S.**

- Too many athletes; could screening really be limited to athletes?
- Very uncommon events
- Too many false positives; also false negatives
- Cost / efficacy considerations
- Infringement on individual prerogative
- Too many lawyers: liability considerations
- Would require mandatory system, based in law, in which physicians would be deciders and enforcers
- No one to perform examinations / interpret ECGs

---

**Bethesda Conference # 36 Recommendations**

**Athletes with the unequivocal diagnosis of hypertrophic cardiomyopathy should not participate in most competitive sports, with the possible exception of those of low intensity.** This recommendation includes those athletes with or without symptoms and with or without left ventricular outflow obstruction.

---

**Should Athletes with Cardiovascular Disease be Permitted to Expose Themselves to Increased Risk by Participating in Competitive Athletics?**
Commotio Cordis:
Sudden Death From Blunt, Non-Penetrating and Relatively Innocent Chest Impact
### Age at Which Commotio Cordis Events Occurred

<table>
<thead>
<tr>
<th>Age in Years</th>
<th>Survivors</th>
<th>Non-survivors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>4-6</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>7-9</td>
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<td>12</td>
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<td>10-12</td>
<td>14</td>
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<td>13-15</td>
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<td>16-18</td>
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<td>19-21</td>
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<td>7</td>
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<tr>
<td>22-24</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>&gt;25</td>
<td>2</td>
<td>1</td>
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</tbody>
</table>

### Blunt Chest Blow and Cardiac Arrest: Sports

- Baseball (n=78)
- Softball (n=28)
- Soccer
- Hockey
- Football
- Lacrosse
- Karate
- Cricket
- Rugby
- Basketball
- Boxing

### Commotio Cordis Events Unassociated With Sports

- Plastic (hollow) toy bat: 1
- Plastic sledging saucer: 1
- Playful (“shadow”)boxing: 6
- Hiccups remedy (by friend): 1
- Head of pet dog (Collie): 1
- Scuffle: 2
- Parent-to-child discipline: 3
- Gang rituals: 2
- Snowball: 1
- Tennis ball (coin filled): 1
- Swing carriage: 1
Commotio Cordis: Determinants

- Location
- Timing
- Force
- Compliant chest wall

Chest Impact Sites

Implement of Chest Impact (n=22)

Commotio Cordis: Determinants

- Location
- Timing
- Force
- Compliant chest wall
Commotio Cordis: Protection

- Everyday Activities
  - Education (never strike the chest)

- Sports
  - AED
  - Chest protectors & Safety-balls

---

---
Commotio Cordis: Protection

- Everyday Activities
- Education (never strike the chest)
- Sports
- AED
- Chest protectors & Safety-balls

(never strike the chest)
Robert Gordon

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- Admitted to psychiatric facility
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ITALY

ARVC
Diurnal Distribution of Sudden Death in Young Athletes

- No. of Athletes

<table>
<thead>
<tr>
<th>Hours</th>
<th>HC</th>
<th>Non - HC</th>
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<tbody>
<tr>
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- # of athletes to be screened = 12 million
- # of exams/ECGs to be performed:
  - 7,890 / year
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Comparison of State History and Physical Examination Preparticipation Screening Forms, 1997 vs. 2005

- No. Recommended AHA Screening Items

% of States

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<th>1997</th>
<th>2005</th>
</tr>
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<td>6.7 to 10.1</td>
<td>66%</td>
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AHA Consensus Panel Recommendations for Preparticipation Athletic Screening

**Family History:**
1. Premature sudden cardiac death
2. Heart disease in surviving relatives

**Personal History:**
3. Heart murmur
4. Systemic hypertension
5. Fatigue
6. Syncope/near-syncope
7. Excessive/unexplained exertional dyspnea
8. Exertional chest pain

**Physical examination:**
9. Heart murmur (supine / standing)
10. Femoral arterial pulses
11. Stigmata of Marfan syndrome
12. Brachial blood pressure measurement (sitting)
Sudden Cardiac Death in Competitive Athletes by Sports

Number of Athletes

Basketball: 45
Football: 25
Track and Running: 10
Soccer: 10
Basketball: 15
Swimming: 5
Volleyball: 5
Ice - Hockey: 5
Boxing: 5
Crew: 5
Ice - Skating: 5
Tennis: 5
Wrestling: 5