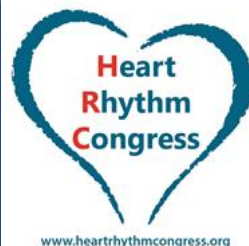# Sudden Cardiac Death Risk in Athletes

St George's Hospital University London
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@SSharmacardio

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

| POPULATION	AGE	DURATION	INCIDENCE
Organised high school[1] and college athletes	13-17	12 years	0.5/100,000
Competitive athletes[2]	14-35	25 years	2/100,000/yr
Marathon (London)[3]	Mean 42	26 years	2.2/100,000 runs
Rhode island jogger[4]	30-65	7 years	13/100,000/yr

1.   Roberts WO. JACC. 2013; 62: 1298
2.   Corrado D. JAMA. 2006; 296: 1953
3.   Tunstall-Pedoe D. Sports Med. 2007; 37: 448
4.   Thompson P. JAMA. 1982; 12: 247

Sudden Cardiac Death in Young Athletes

Harmon. Heart. 2014; 15: 1185-1192

- 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)

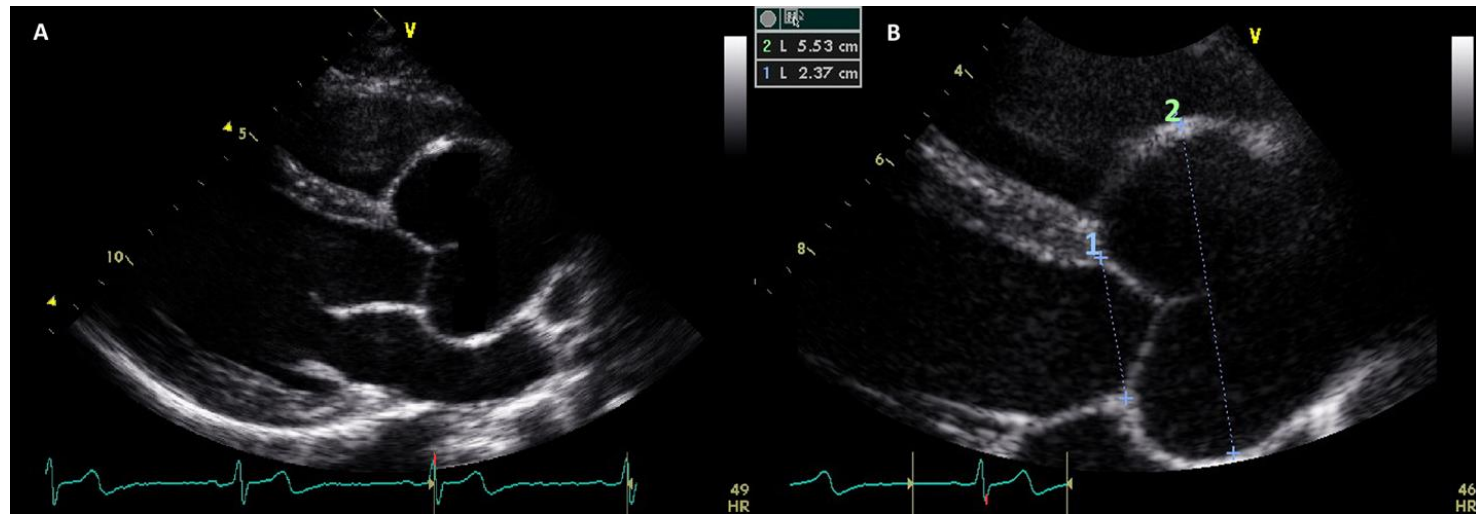- Black athletes > white athletes

- 90% deaths during or immediately after exertion

Sudden Cardiac Death in Sport
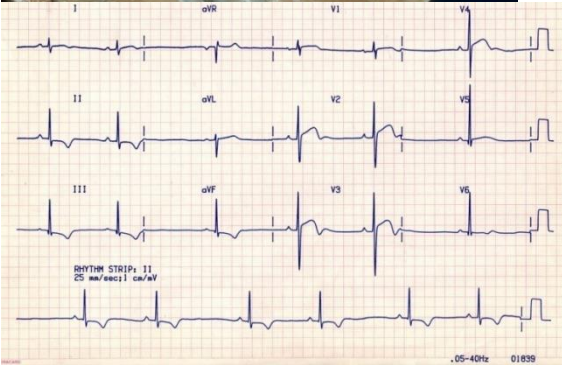
Hypertrophic Cardiomyopathy

Arrhythmogenic right ventricular cardiomyopathy

Coronary arteries and aorta

Sudden Cardiac Death with a Normal Heart
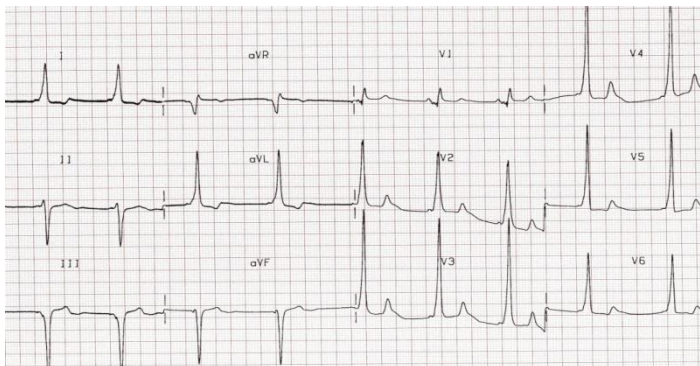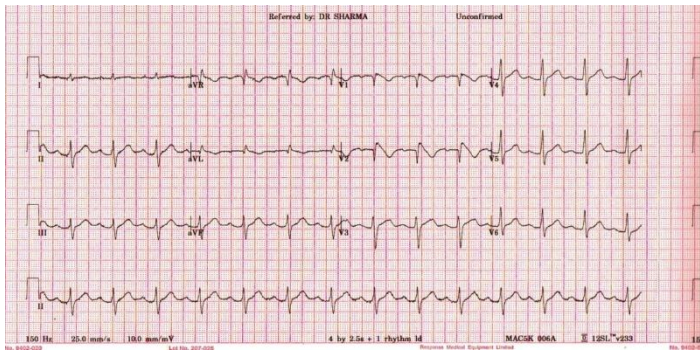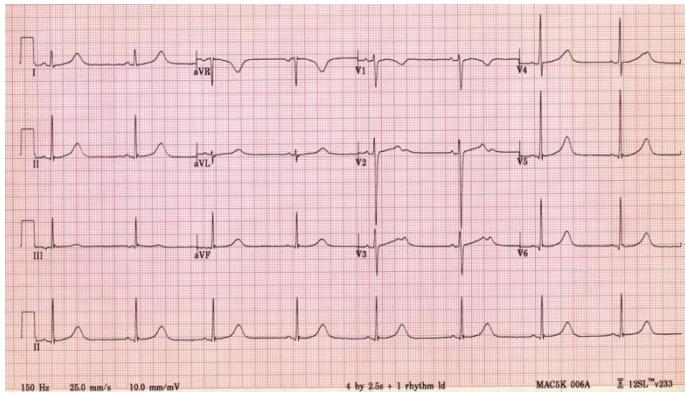
LQTS

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.

A. Sudden Death in Overall Population

- Arrhythmogenic Right Ventricular Cardiomyopathy
- Sudden Arrhythmic Death Syndrome
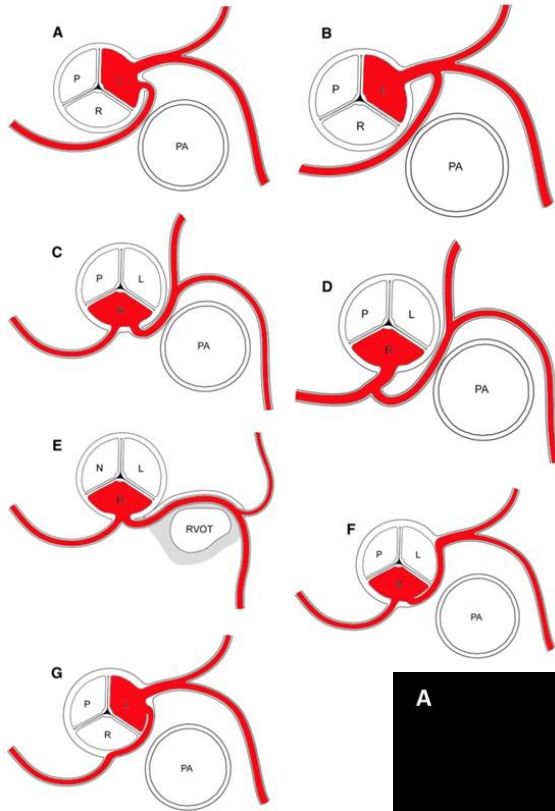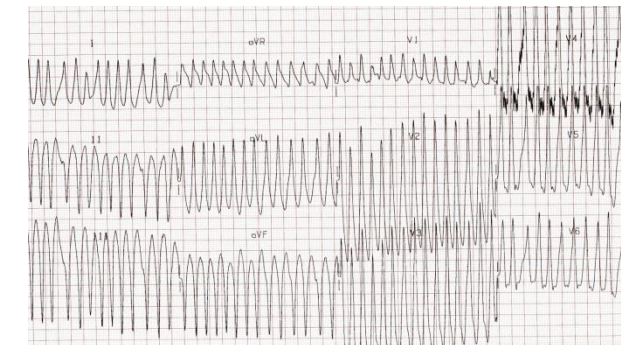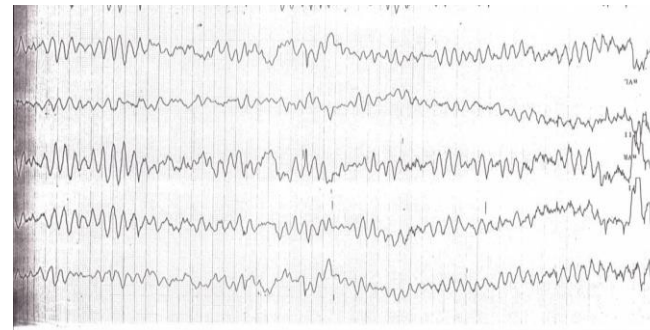- Coronary Artery Anomaly
- Coronary Atheroma
- Myocarditis
- Idiopathic LVH/Fibrosis
- Dilated Cardiomyopathy
- Hypertrophic Cardiomyopathy
- Other

42%, 16%, 13%, 12%, 6%, 5%, 2%, 2%, 1%

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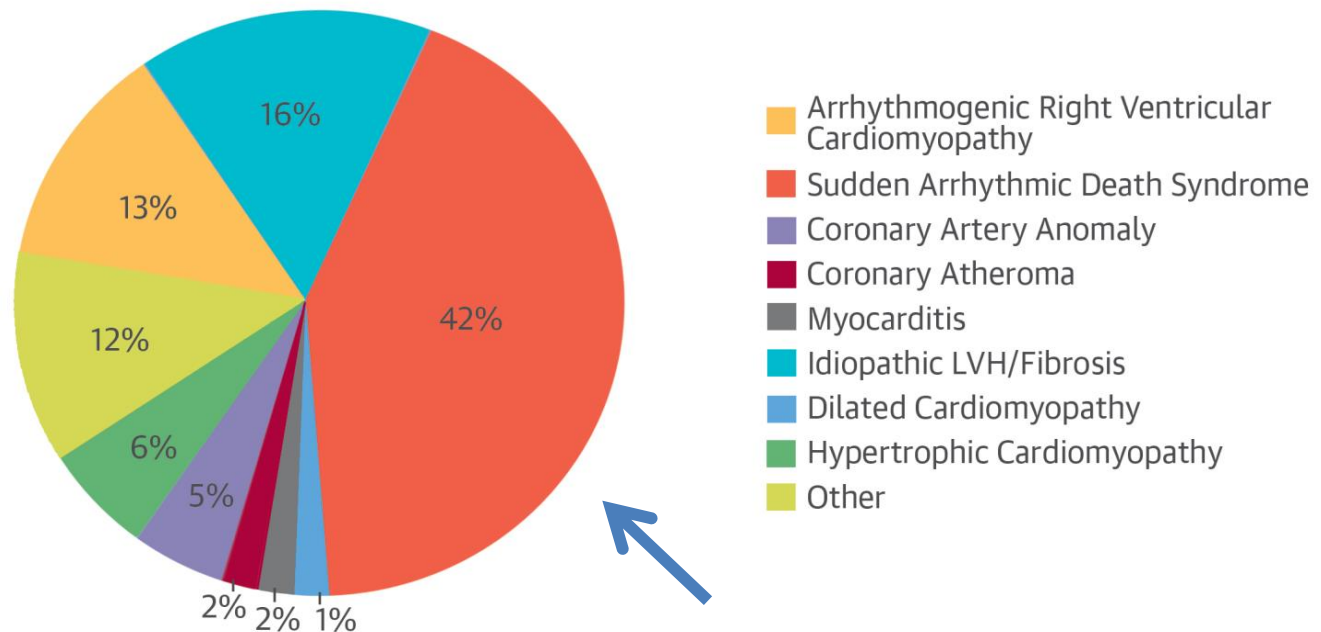
Triggers for Sudden Cardiac Death

Dehydration

Adrenergic surges
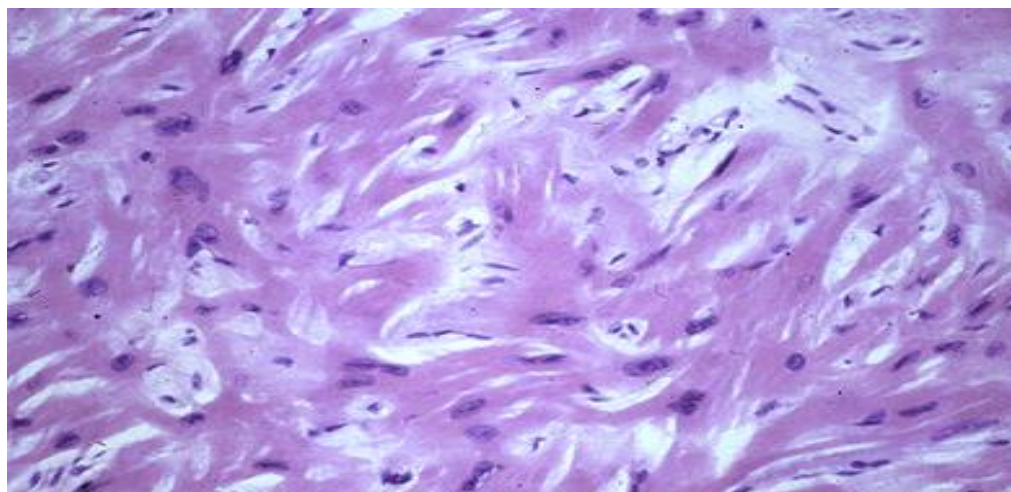
Electrolyte imbalance

Acid/base disturbance

ac **R**isk *in the* **Young**
| **Centre** *for* **Sports Cardiology**
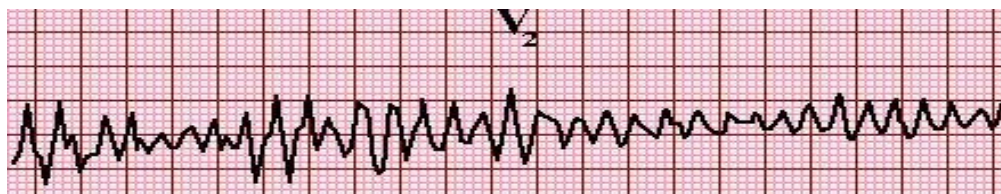
Screening Strategies for Detecting Athletes with Potentially Serious Cardiac Disease
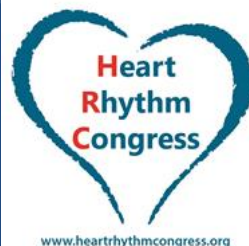
Screening Athletes

Condition	History	Examn	ECG	Echo
HCM	Pos/Neg	Pos in 25%	Positive	Pos
ARVC	Pos/Neg	Negative	Positive	Neg/Pos
WPW	Pos/Neg	Negative	Positive	Neg
LQTS	Pos/Neg	Negative	Positive	Neg
Marfan	Pos/Neg	Positive	Negative	Pos
CAA	Pos/Neg	Negative	Negative	Neg
Myocarditis	Pos/Neg	Pos/Neg	Pos/Neg	Pos

INCREASING COST

American Heart Association
Learn and Live

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
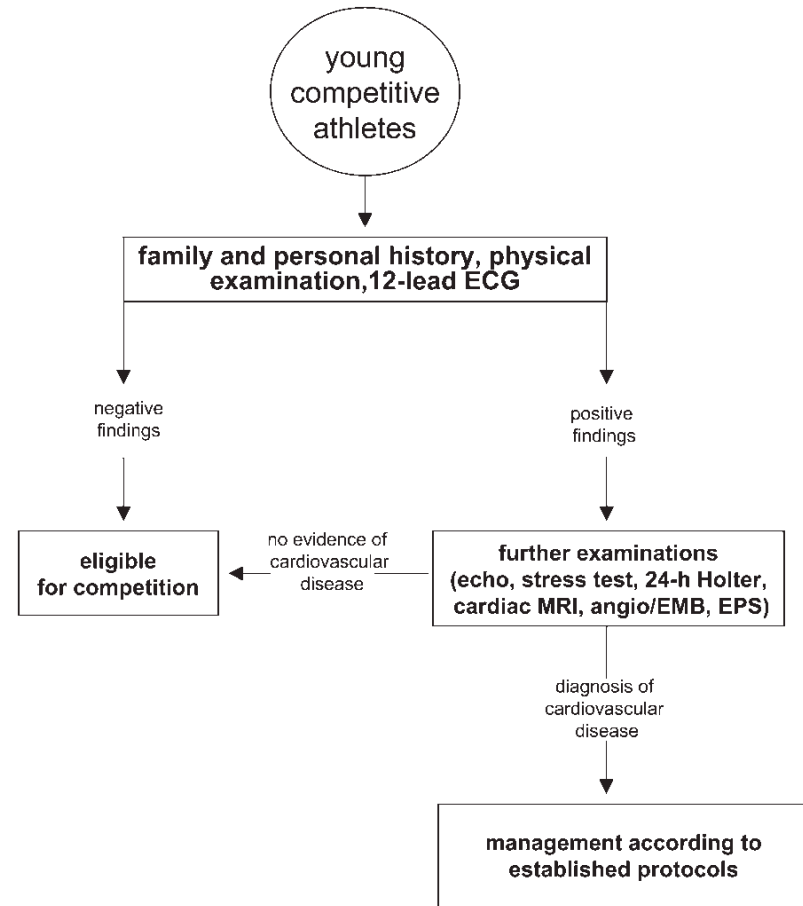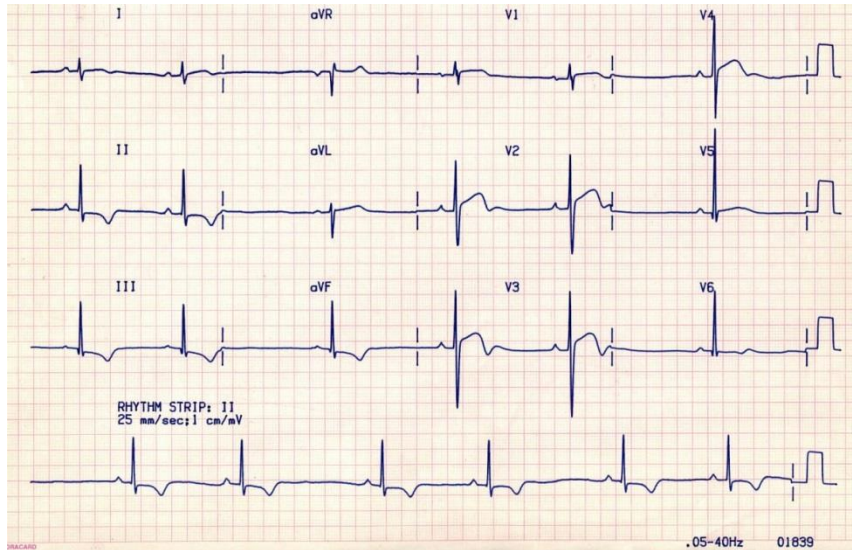
Physical examination

9. Heart murmur‡

10. Femoral pulses to exclude aortic coarctation

11. Physical stigmata of Marfan syndrome

12. Brachial artery blood pressure (sitting position)§

EUROPEAN SOCIETY OF CARDIOLOGY®

```
        ┌──────────────┐
        │    young     │
        │ competitive  │
        │   athletes   │
        └──────┬───────┘
               ↓
 ┌──────────────────────────────────┐
 │ family and personal history,      │
 │ physical examination,12-lead ECG  │
 └────┬─────────────────────────┬───┘
      │                         │
  negative                  positive
  findings                  findings
      │                         │
      ↓                         ↓
┌──────────────┐  no evidence   ┌──────────────────────┐
│  eligible    │  of cardio-    │ further examinations │
│ for compet-  │← vascular      │ (echo, stress test,  │
│ ition        │  disease       │ 24-h Holter, cardiac │
└──────────────┘                │ MRI, angio/EMB, EPS) │
                                └──────────┬───────────┘
                                      diagnosis of
                                      cardiovascular
                                      disease
                                           ↓
                                ┌──────────────────────┐
                                │ management according │
                                │ to established       │
                                │ protocols            │
                                └──────────────────────┘
```

Cardiac Risk *in the* **Young**
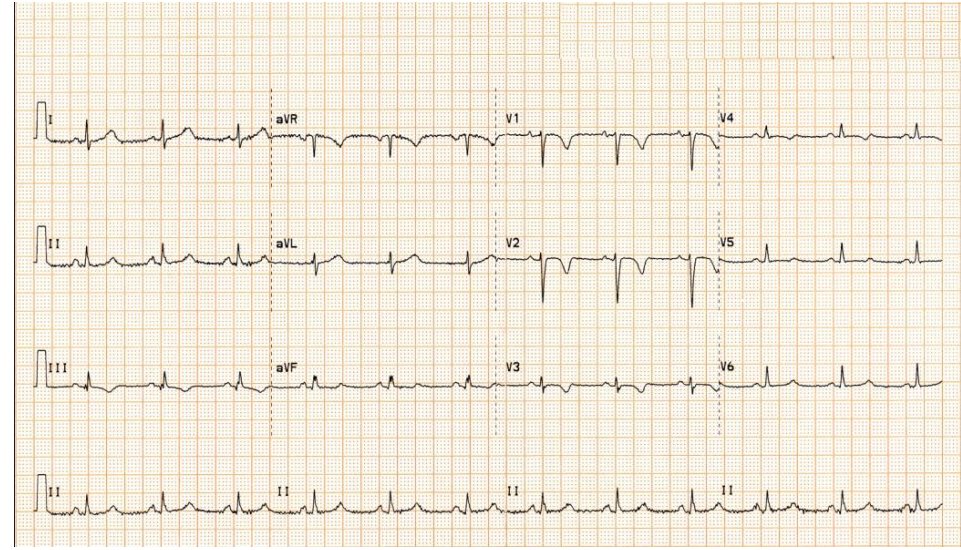**Centre** *for* **Sports Cardiology**

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)
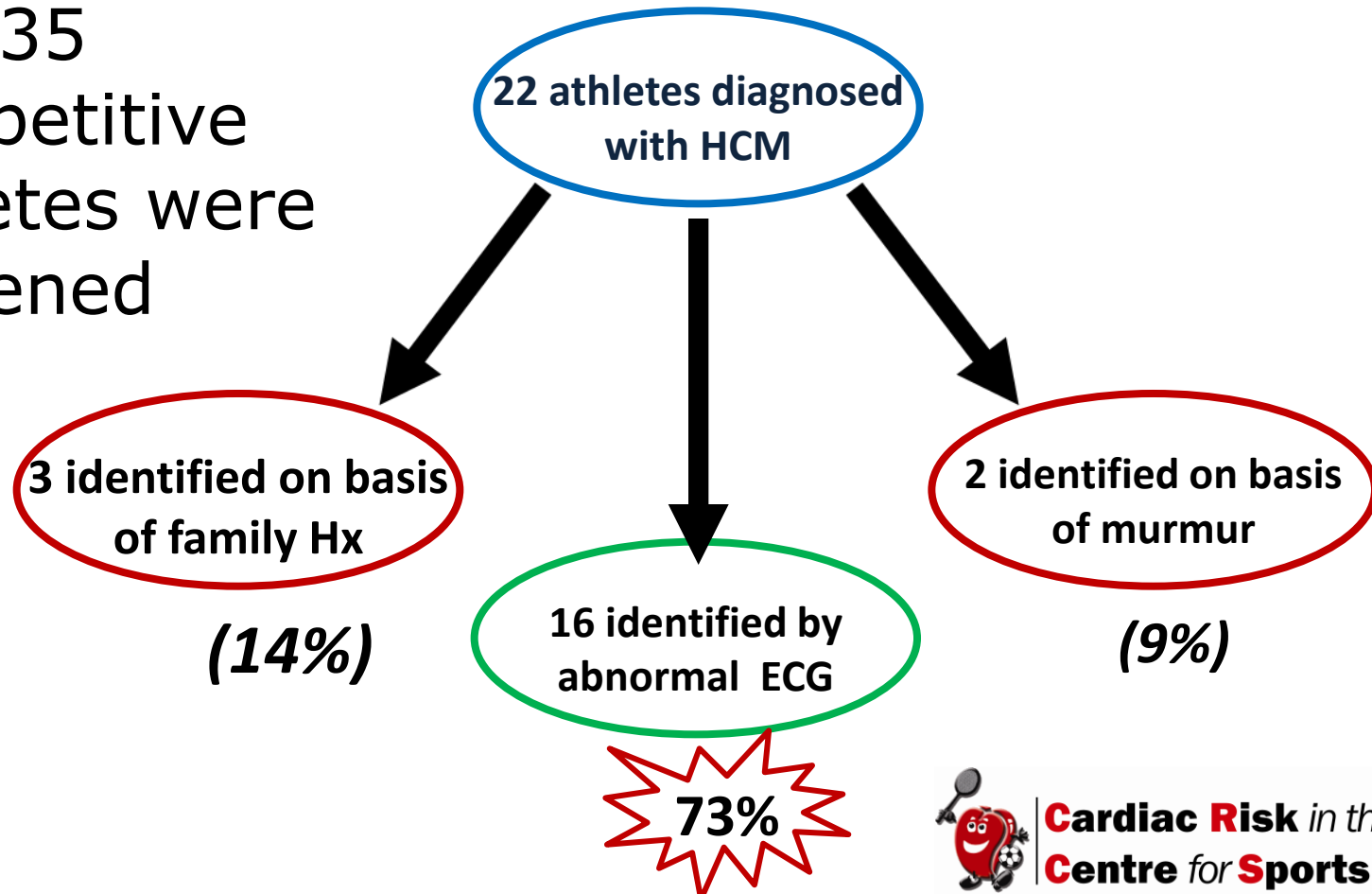with isoelectric J point
Epsilon wave
Ventricular extra-systoles

SCREENING FOR HYPERTROPHIC CARDIOMYOPATHY IN YOUNG ATHLETES

DOMENICO CORRADO, M.D., CRISTINA BASSO, M.D., MAURIZIO SCHIAVON, M.D., AND GAETANO THIENE, M.D.

33,735 competitive athletes were screened

22 athletes diagnosed with HCM

3 identified on basis of family Hx

(14%)

16 identified by abnormal ECG

73%

2 identified on basis of murmur

(9%)

Cardiac Risk in the Young
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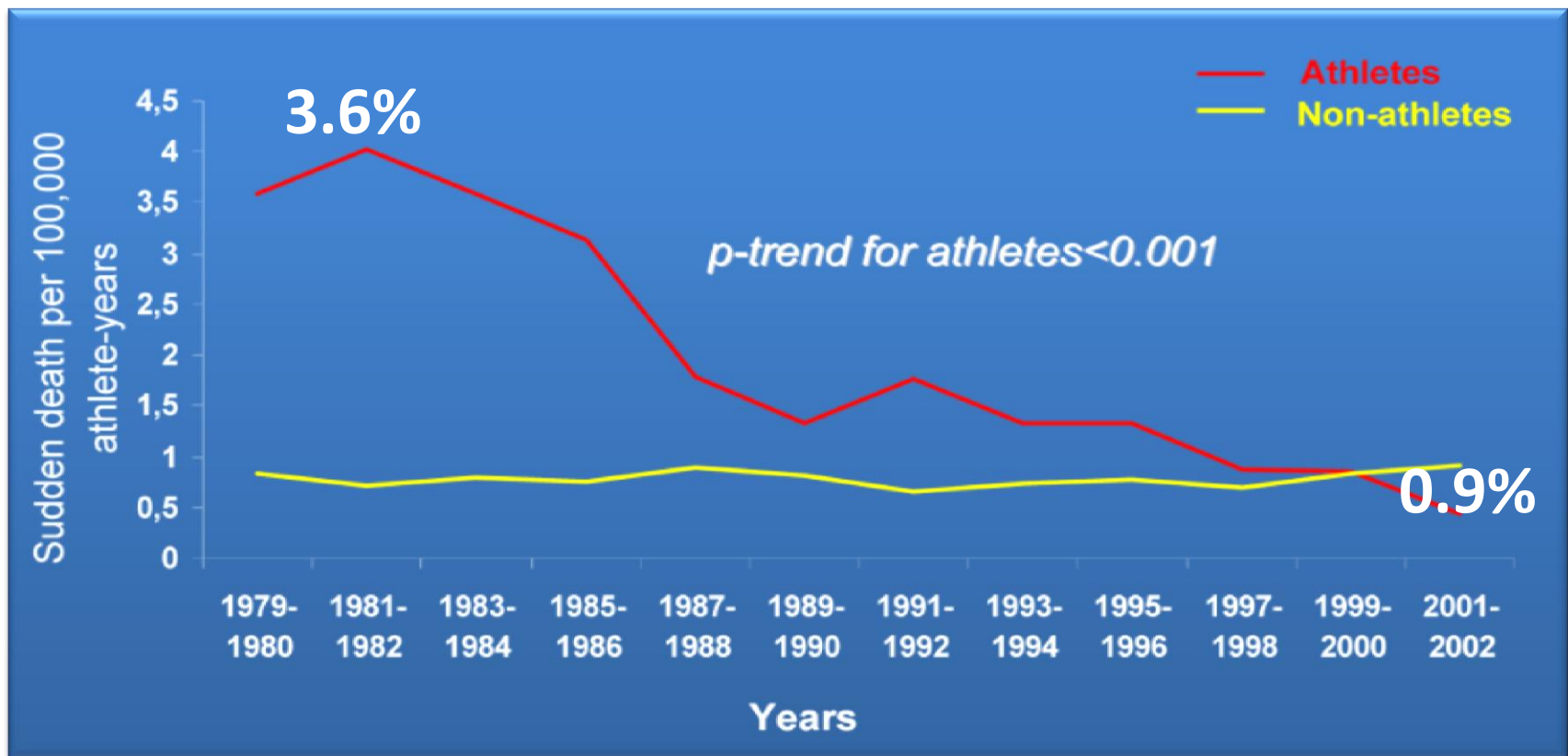
Does Cardiac Screening Save Lives?

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
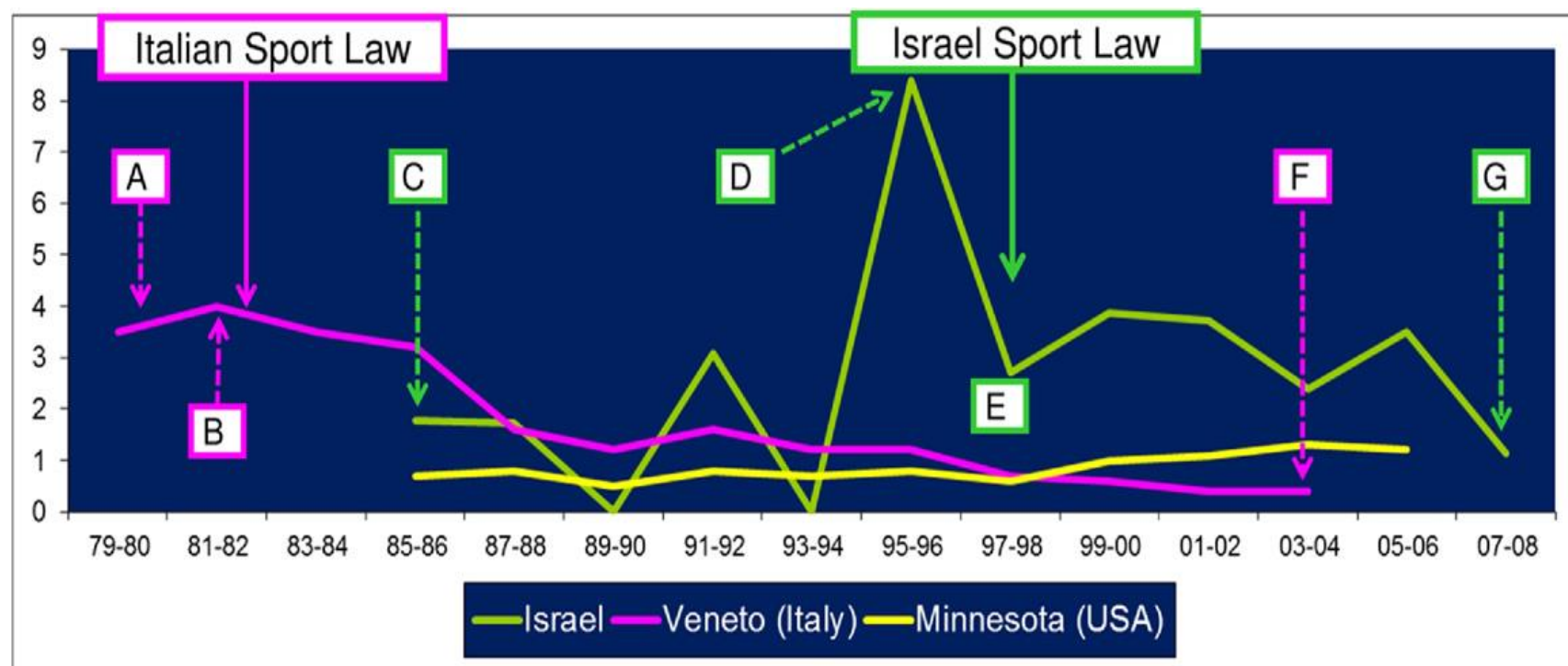
Concerns Regarding ECG Screening

Concerns Relating to ECG Screening

Low incidence of sudden cardiac death

High number of false positives

Cost

Concerns relating to false negatives

Cardiac Risk in the Young
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Prevalence of Young Athletes with Conditions Predisposing to SCD

Reference	Population	Prevalence
AHA (2007)	Competitive athletes (U.S.)	0.3%
Fuller (1997)	5,617 high school athletes (U.S)	0.4%
Corrado (2006)	42,386 athletes age 12-35 (Italy)	0.2%
Wilson (2008)	2,720 athletes /children age 10-17	0.3%
Bessem (2009)	428 athletes age 12-35 (Netherlands)	0.7%
Baggish (2010)	510 collegiate athletes	0.6%
Sheikh (2015)	5000 British elite athletes	0.3%

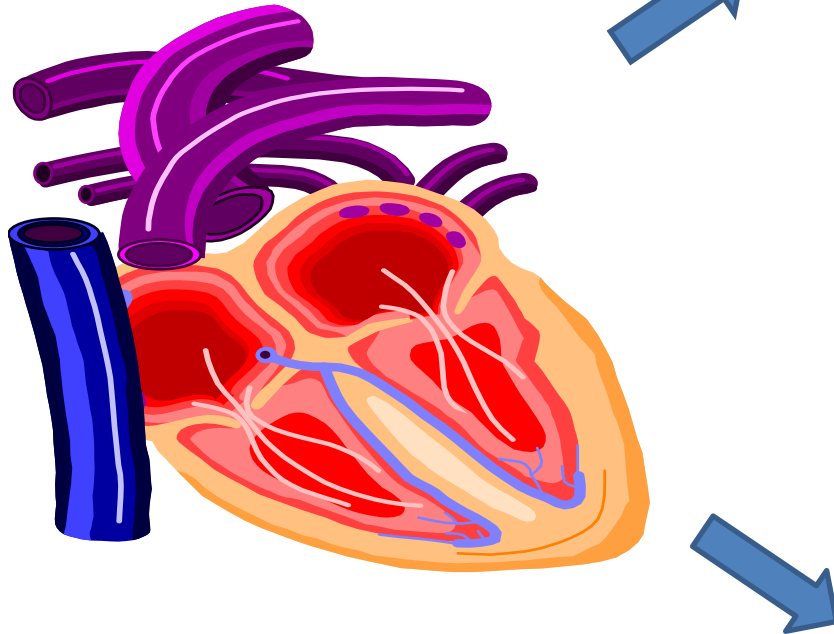# Concerns Relating to ECG Screening

Low incidence of sudden cardiac death

High number of false positives

Cost

Concerns relating to false negatives

Cardiac **R**isk *in the* **Y**oung
Centre *for* **S**ports **C**ardiology

ECG in Athletes

VAGOTONIA

Bradycardia

AV block

Repolarisation anomalies

CHAMBER ENLARGEMENT

Sokolow-Lyon Voltage criterion for LVH

Incomplete RBBB
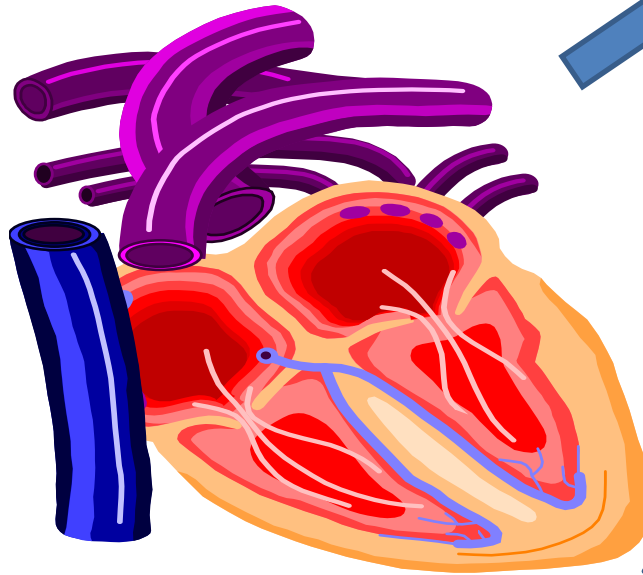
ECG in Athletes

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

(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

Cardiac Risk *in the* **Young**
Centre *for* **Sports Cardiology**

European Heart Journal
doi:10.1093/eurheartj/ehr140
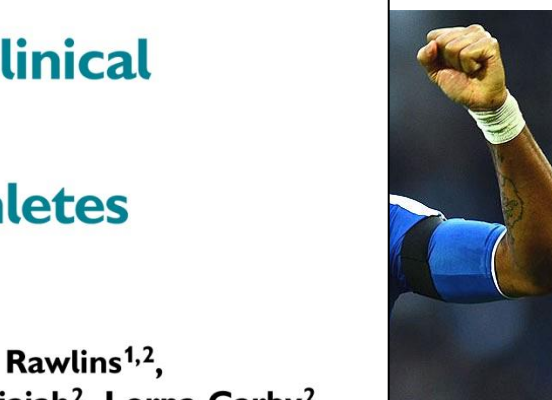
The prevalence, distribution, and clinical outcomes of electrocardiographic repolarization patterns in male athletes of African/Afro-Caribbean origin

Michael Papadakis[1,2], Francois Carre[3], Gaelle Kervio[4], John Rawlins[1,2], Vasileios F. Panoulas[2], Navin Chandra[1,2], Sandeep Basavarajaiah[2], Lorna Carby[2], Tiago Fonseca[2], and Sanjay Sharma[1,2]*

[1]St George's University of London, Cranmer Terrace, SW17 0RE, London, UK; [2]University Hospital Lewisham, London, UK; [3]French Institute of Health and Medical Research (INSERM), U642, Rennes, F-35000, France; and [4]French Institute of Health and Medical Research (INSERM), CIC-IT 804, Rennes, F-35000, France

Prevalence of Abnormal ECG Patterns in Athletes

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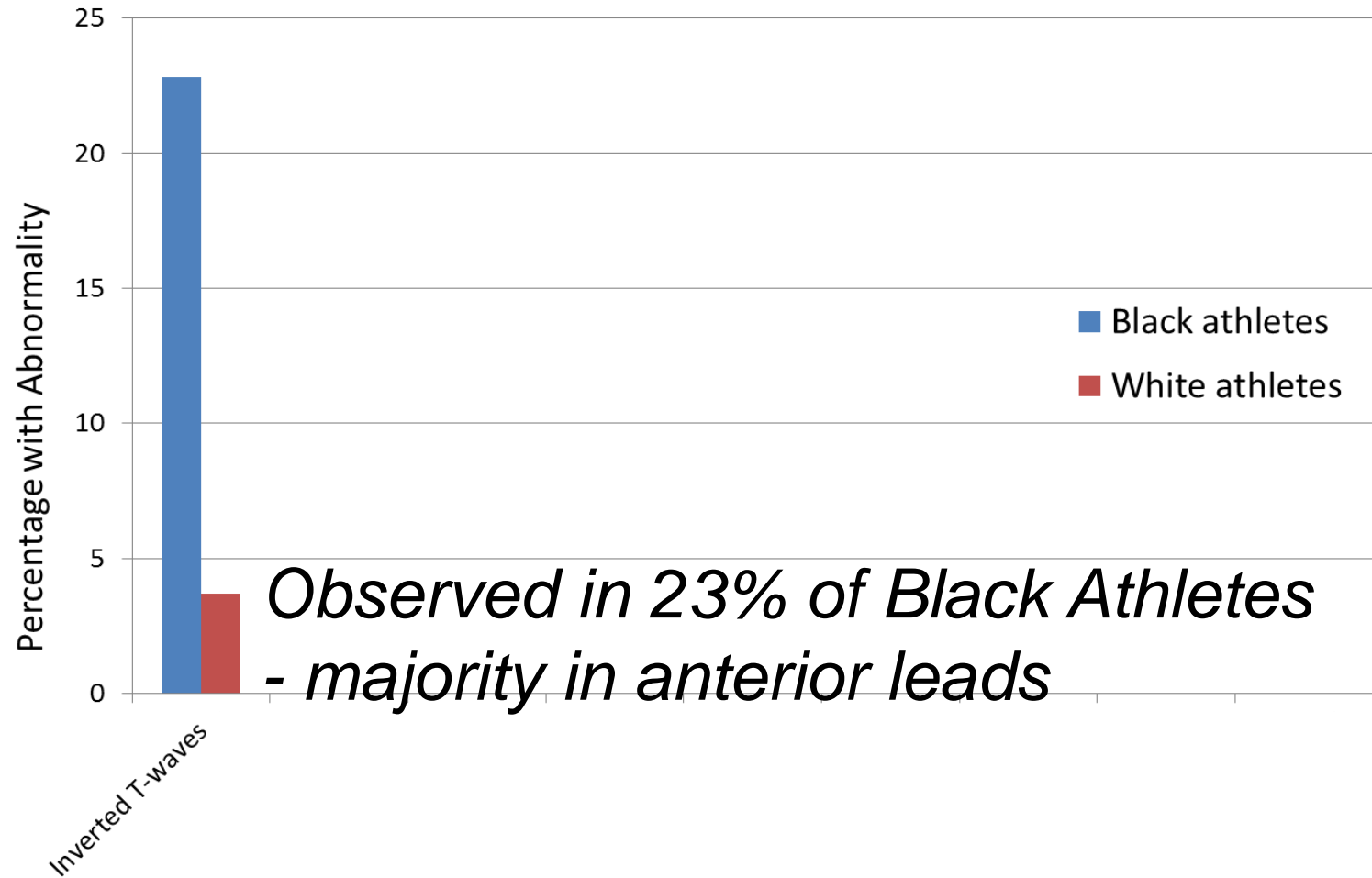
TWI in a Black Athletes

Male

Vent. rate   64 bpm
PR interval   160 ms
QRS duration   96 ms
QT/QTc   468/482 ms
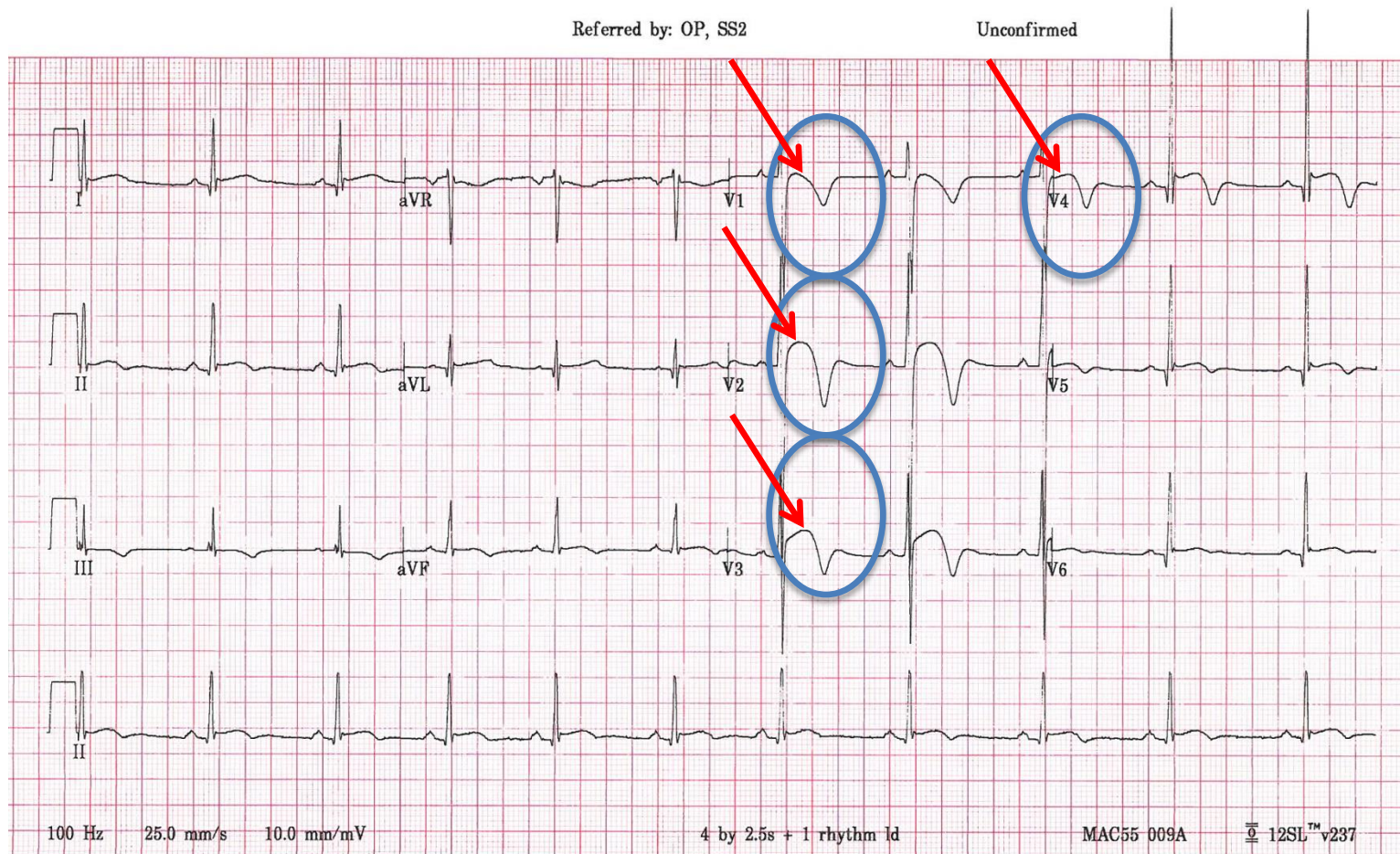P-R-T axes   41 55 4

Technician: SW

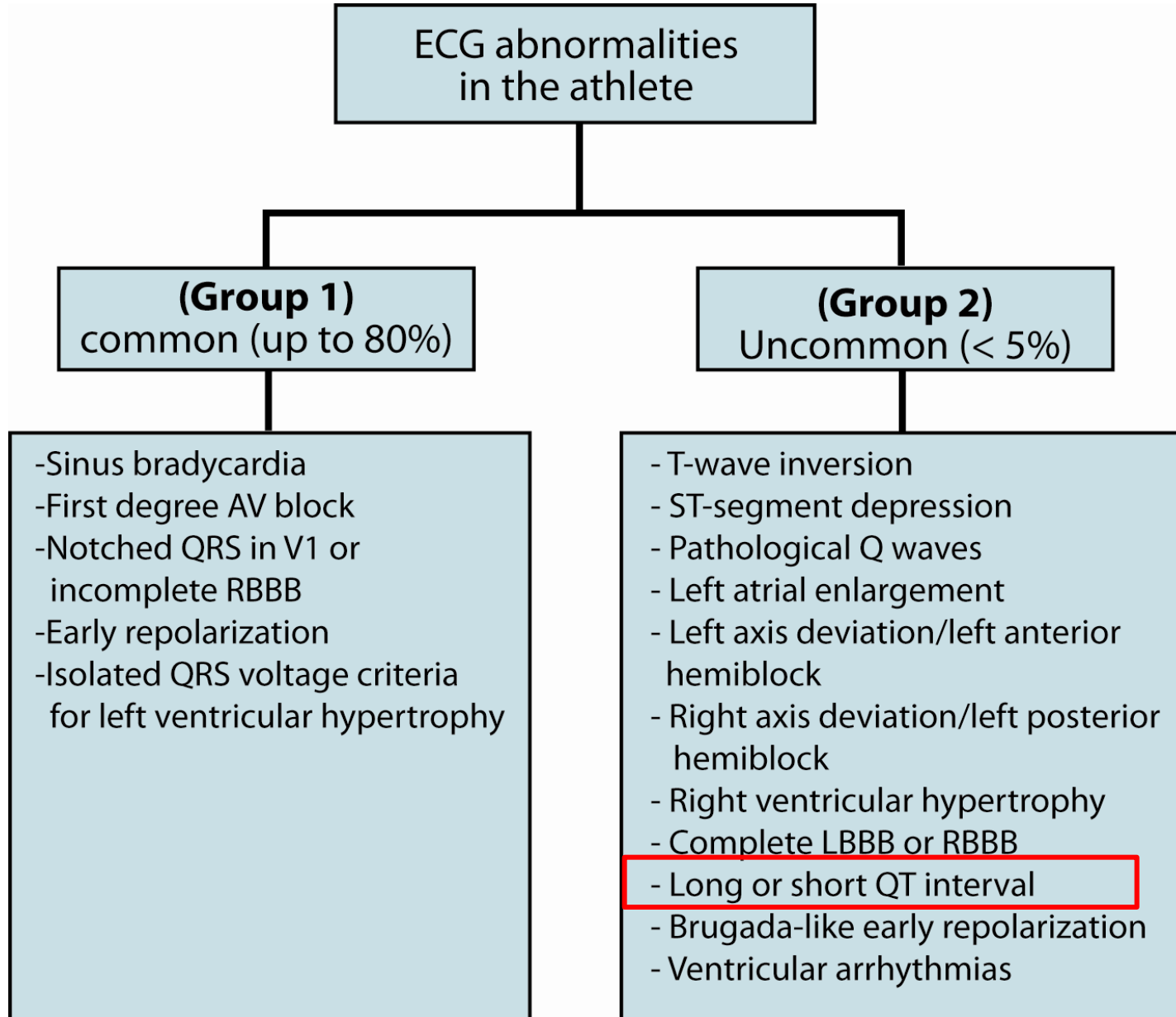**12.4%**

Referred by: OP, SS2   Unconfirmed

100 Hz   25.0 mm/s   10.0 mm/mV   4 by 2.5s + 1 rhythm ld   MAC55 009A   12SL™v237

MedGRAPHICS LTD REGULAR   30.319

Young
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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

Cardiac Risk in the Young
Centre for Sports Cardiology

Box 1   Normal ECG findings in athletes

1. Sinus bradycardia ($\geq$30 bpm)
2. Sinus arrhythmia
3. Ectopic atrial rhythm
4. Junctional escape rhythm
5. First-degree AV block (PR interval>200 ms)
6. Mobitz type I (Wenckebach) second-degree AV block
7. Incomplete RBBB
8. Isolated QRS voltage criteria for LVH
   - Except:QRS voltage criteria for LVH occurring with any non-voltage criteria for LVH such as left atrial enlargement, left axis deviation, ST segment depression, T wave inversion or pathological Q waves
9. Early repolarisation (ST elevation, J-point elevation, J waves, or terminal QRS slurring)
10. Convex ('domed') ST segment elevation combined with T wave inversion in leads V1–V4 in black/African athletes.

These common training-related ECG alterations are physiological adaptations to regular exercise, considered normal variants in athletes, and do not require further evaluation in asymptomatic athletes.
   AV, atrioventricular; bpm, beats per minute; LVH, left ventricular hypertrophy; RBBB, right bundle branch block.

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

Clinical research

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

Sandeep Basavarajaiah[1], Matthew Wilson[2], Gregory Whyte[3], Ajay Shah[1], Elijah Behr[4], and Sanjay Sharma[1]*

CLINICAL RESEARCH
Sports cardiology

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 Gati[1,2], Nabeel Sheikh[1], Saqib Ghani[1], Abbas Zaidi[1], Mathew Wilson[3], Hariharan Raju[1], Andrew Cox[1], Matt Reed[1], Michael Papadakis[1], and Sanjay Sharma[1,2]*

[1]St George's University of London, Cranmer Terrace, SW17 0RE, London SE5 9RS, UK; [2]University Hospital Lewisham, London, UK; and [3]Aspetar, Department of Sports Medicine, Qatar Orthopaedic and Sports Medicine Hospital, Doha, Qatar

CLINICAL RESEARCH

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

Michael Papadakis[1,2], Francois Carre[3], Gaelle Kervio[4], John Rawlins[1,2], Vasileios F. Panoulas[2], Navin Chandra[1,2], Sandeep Basavarajaiah[2], Lorna Carby[2], Tiago Fonseca[2], and Sanjay Sharma[1,2]*

[1]St George's University of London, Cranmer Terrace, SW17 0RE, London, UK; [2]University Hospital Lewisham, London, UK; [3]French Institute of Health and Medical Research (INSERM), U642, Rennes, F-35000, France; and [4]French Institute of Health and Medical Research (INSERM), CIC-IT 804, Rennes, F-35000, France

CLINICAL RESEARCH
Sports cardiology

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 Bastiaenen, Brendan Madden, Michael Papadakis[†], Hariharan Raju[†], Matthew Reed, Rajan Sharma, Elijah R. Behr, and Sanjay Sharma[†]*

Division of Cardiovascular Sciences, St George's University of London (SGUL), Cranmer Terrace, SW17 0RE London, UK

Original Article

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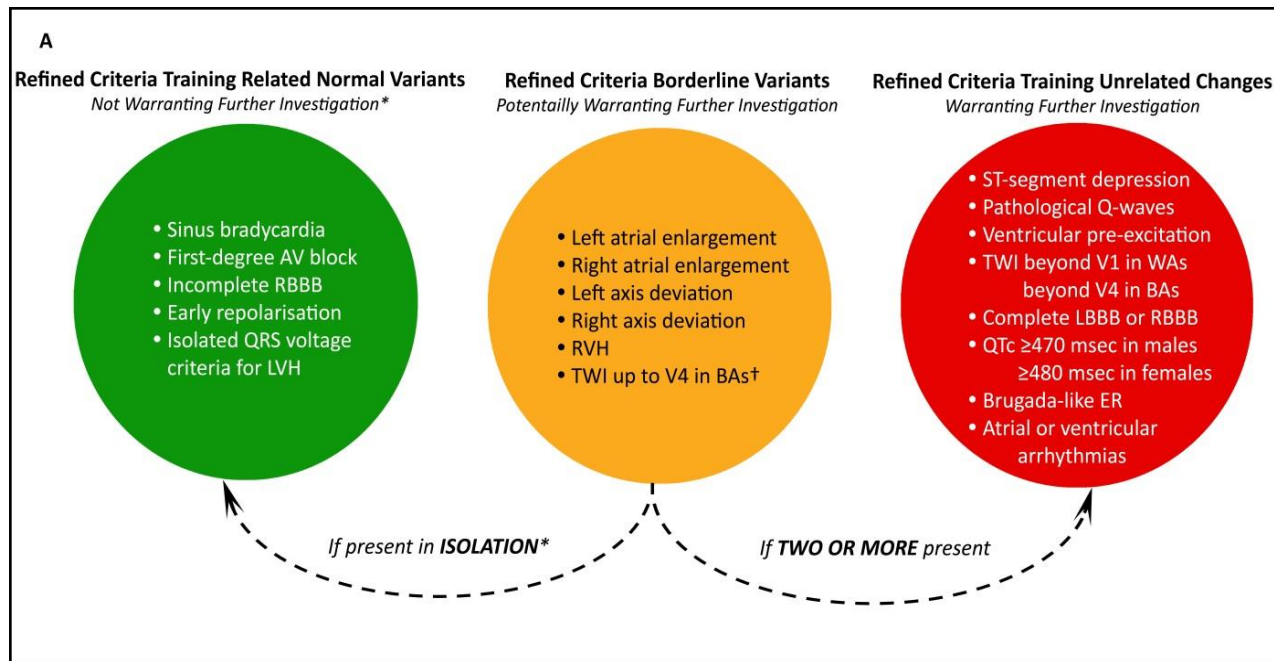
Sensitivity for all conditions	60%
Sensitivity for serious conditions	100%
Specificity	94% in Caucasians
	84% in Black athletes

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 <30bpm**
- **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**
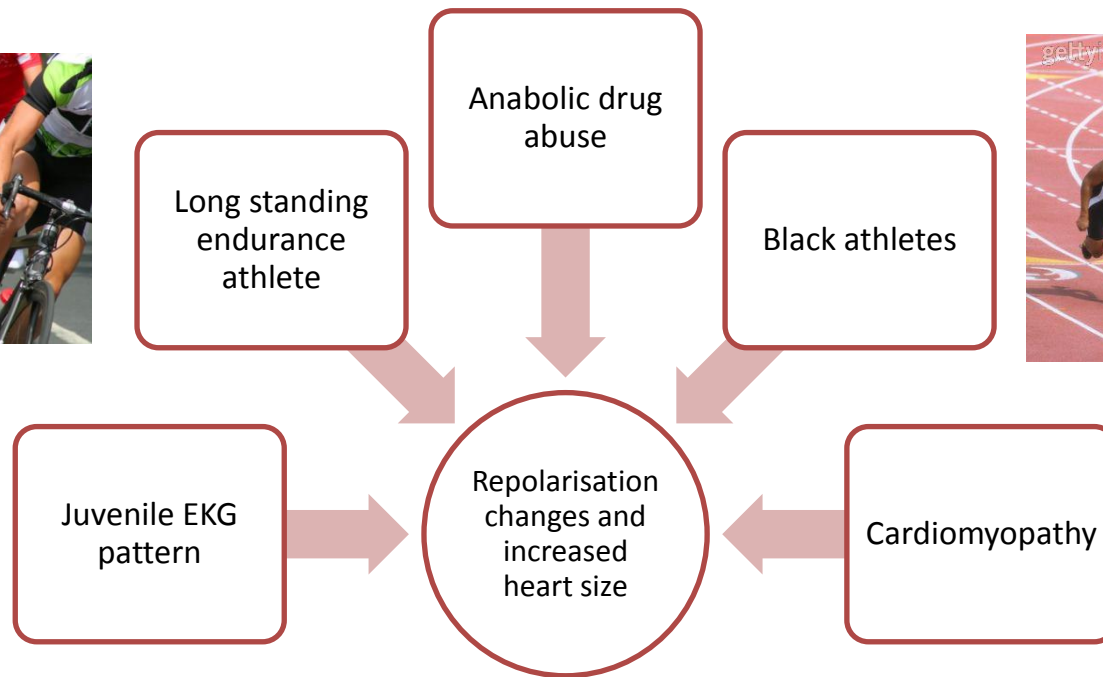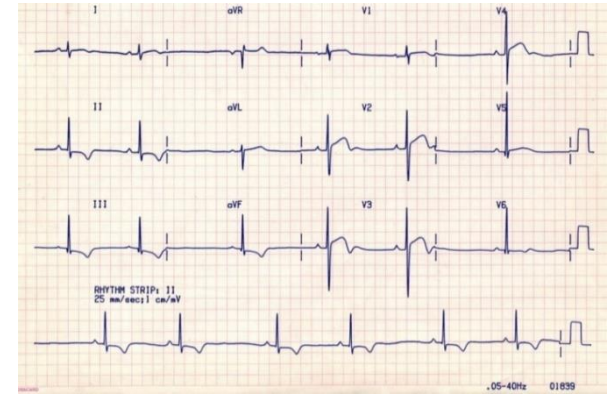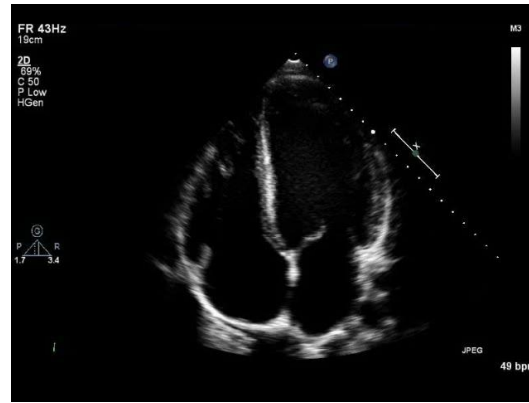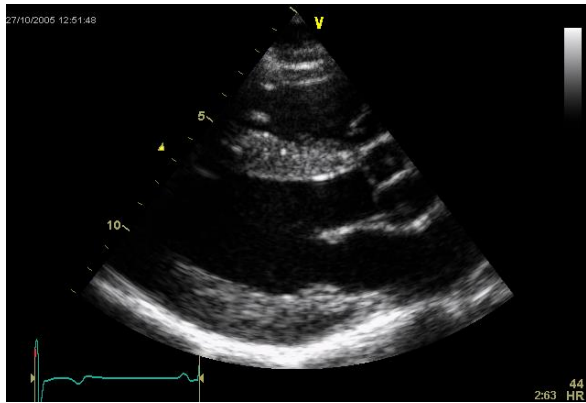
In isolation

2 or more

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

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

Cardiac Risk *in the* **Young**
Centre *for* **Sports Cardiology**

Overlap With Disease

Long standing endurance athlete

Anabolic drug abuse

Black athletes

Juvenile EKG pattern

Repolarisation changes and increased heart size

Cardiomyopathy

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

Cardiac Risk *in the* **Young**
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Alternative Strategies

Exercise related cardiac arrest
Incidence in the general population France (2005 – 2010)

Sports-Related Sudden Death in the General Population

Eloi Marijon, MD; Muriel Tafflet, PhD; David S. Celermajer, PhD, FRACP; Florence Dumas, MD;
Marie-Cécile Perier, MSc; Hazrije Mustafic, MD; Jean-François Toussaint, MD, PhD;
Michel Desnos, MD; Michel Rieu, MD; Nordine Benameur, MD; Jean-Yves Le Heuzey, MD;
Jean-Philippe Empana, MD, PhD; Xavier Jouven, MD, PhD

Mean age 46.1 ± 15.8.   93% Male.

Survival 15%

Exercise related cardiac arrest

Incidence in the general population Netherlands (2006 – 2009)

Exercise-related out-of-hospital cardiac arrest in the general population: incidence and prognosis

Jocelyn Berdowski[1], Margriet F. de Beus[2,3], Marieke Blom[4], Abdennasser Bardai[4], Michiel L. Bots[2], Pieter A. Doevendans[3,5], Diederick E. Grobbee[2,6], Hanno L. Tan[4], Jan G.P. Tijssen[1], Rudolph W. Koster[1], and Arend Mosterd[2,3,7]*

Mean age 58.8 ± 13.6.   95% Male.

Survival 45%

Cardiac Risk *in the* **Young**
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Exercise related cardiac arrest

Country	Netherlands	France
Age, years	58.8 ± 13.6	46.1 ± 15.8
Success rate	45%	15%
Men	93%	95%
Bystander witnessed arrest	89%	94%
Bystander CPR	87%	31%
AED use	36%	1%
Shockable initial rhythm	80%	47%
Time to first shock (min)	9.8 (6.4 – 12.5)	12.5 (10.5 – 15.5)

Cardiac Arrest during Long-Distance Running Races

10.9 million runs

59 deaths.   29 % survival death rate

FACTOR	ODDS RATIO
By stander CPR	3.73 CI 2.19-6.39
Time of collapse to CPR	1.32 CI 1.08-1.61
Initial use of AED	3.71 CI 2.07-6.64

Drezner 2009

Report of 1710 US high schools with an on-site AED program. Survey relating to sudden cardiac arrest (SCA) between Jan 2006-July 2007
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
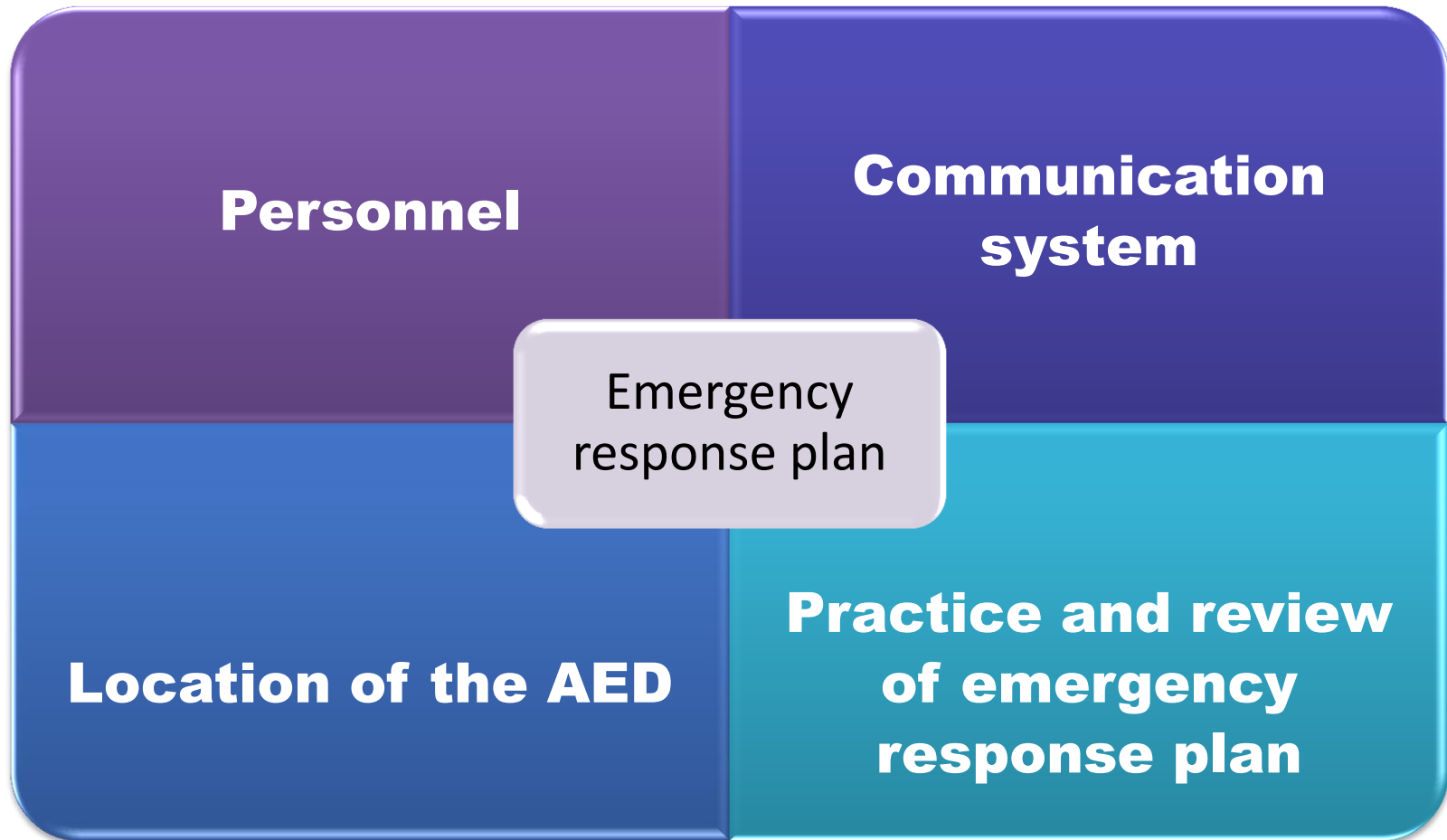
- Mean time from collapse to CPR

1.5 Minutes

- Mean time from SCA to first shock

3.6 Minutes

Cardiac Risk *in the* **Young**
Centre *for* **Sports Cardiology**

The Emergency Response Plan

Personnel

Communication system

Emergency response plan

Location of the AED

Practice and review of emergency response plan

Cardiac Risk in the Young
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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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