EVALUATION OF ELECTROCARDIOGRAPHIC FINDINGS IN ATHLETES

UNIT OF INHERITED CV DISEASES
HEART CENTER OF THE YOUNG AND ATHLETES
A DPT OF CARDIOLOGY UNIVERSITY OF ATHENS
EVALUATION OF ELECTROCARDIOGRAPHIC FINDINGS IN ATHLETES

- ITALIAN EXPERIENCE
- LONDON GROUP
- ESC RECOMMENDATION
  - IOC
  - NBA
  - UEFA
CARDIOVASCULAR PREPARTICIPATION 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 Cardiac Rehabilitation and Exercise Physiology and the Working Group of Myocardial and Pericardial diseases of the European Society of Cardiology
young competitive athletes

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

- negative findings: eligible for competition
- positive findings: further examinations (echo, stress test, 24-h Holter, cardiac MRI, angio/EMB, EPS)

no evidence of cardiovascular disease

diagnosis of cardiovascular disease: management according to established protocols

Bradycardia
Repolarisation anomalies
Voltage criteria for chamber enlargement
Arrhythmias

Increased chamber wall thickness and cavity size

Enhanced diastolic filling
Augmentation of stroke volume
EUROPEAN RECOMMENDATIONS

Eur Heart J 2010

• A modern approach to correct interpretation of 12-lead ECG in the athlete and emerging understanding of incomplete penetrance of inherited cardiovascular disease
ATHLETES ECG

• Cardiovascular remodelling in the conditioned athlete is frequently associated with physiologic ECG changes.

• Abnormalities, however, may be detected which represent expression of an underlying heart disease which puts the athlete at risk of arrhythmic cardiac arrest during sport.
Athletes ECG interpretation

The aim

• is to provide a framework for this distinction.

EUROPEAN RECOMMENDATIONS
Eur Heart J 2010
Abnormal ECG in Athletes

- Pelliccia et al (40%)
  *Circ* 2000

- Corrado et al (11%)
  *Eur Heart J* 2010

- Le VV et al (10%)
  *Clin J Sport Medicine* 2010
Abnormal electrocardiographic patterns in elite athletes: the Greek experience

Objectives

• There is a wide clinical perception that routine implementation of 12 lead electrocardiogram (ECG) will convey a large proportion (20-40%) of abnormal findings

• requiring additional testing to resolve the ambiguity of cardiovascular diagnosis and

• raising substantially the cost of screening.
460 elite Athletes

- Weight lifting
- Water polo
- Short distance running
- Wrestling
- Basketball
- Football
- Pentathlon & Eptathlon
- Synchronized swimming
- Wrestling
- Short distance running
- Long distance running
- Water polo
- Cycling
- Gymnastics
- Volleyball
- Rowing
- Sailing
- Taekwondo

Track and field events
Most frequent benign ECG abnormalities

- Left ventricular hypertrophy: 28%
- Sinus bradycardia: 29%
- Early repolarization pattern: 24%
Distinct abnormalities (57 athletes – 12.4%)

460 elite athletes
ECG abnormalities suspicious for underlying cardiac disease less than 7%

- V1-V3 inverted T-waves 5 (1.1%)
- V1-V2 inverted T-waves 6 (1.3%)
- LVH and repolarization abnormalities 16 (3.5%)
- QTc interval ≥ 450msec males, 460ms females (0.5%)

- do not exceed 7% of the overall study population.
A correct evaluation of 12-lead ECG patterns

• A correct evaluation of 12-lead ECG patterns in the athlete and appropriate subsequent action has the potential
• to increase efficacy,
• accuracy and
• cost-effectiveness

of athlete’s cardiovascular evaluation

EUROPEAN RECOMMENDATIONS
Eur Heart J 2010
Inherited cv diseases

• There is growing experience of early and incomplete disease expression of the inherited cardiomyopathies and

• arrhythmias which usually have ECG changes as their initial presentation

• EUROPEAN RECOMMENDATIONS
  Eur Heart J 2010
College basketball standout Hank Gathers, after he collapsed and later died of ventricular fibrillation due to cardiomyopathy during a game in Los Angeles, March 5, 1990. (Photograph by Gary Friedman. From The Los Angeles Times Syndicate, Los Angeles, CA, 1990, by permission.)
Distribution of cardiovascular causes of sudden death in 1435 young competitive athletes

Unexplained sudden death
Tann et al Circulation 2005

• 40% FAMILIAL CV DISEASES

• P VT : 5 FAM
• LQTS : 4 FAM
• BRUG : 2 FAM
• ARVC : 3 FAM
• HCM : 1 FAM
• F DYSL : 1 FAM
Causes of sudden cardiac death in the young

- Hypertrophic cardiomyopathy
- Arrhythmogenic right ventricular cardiomyopathy
- SADS
- Coronary artery anomalies
- Premature coronary artery disease
- Myocarditis
- Wolff-Parkinson-White
EVALUATION OF ELECTROCARDIOGRAPHIC FINDINGS IN ATHLETES

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Training related ECG changes

- Increased QRS voltage
- Early repolarization
- Manifestations of increased vagal tone
actual left ventricular hypertrophy

without

- Axis changes,
- changes in repolarization,
- atrial abnormalities,
- increased QRS width

- **High QRS voltage** is not a sufficient reason in isolation to refer an athlete for further evaluation.
Early Repolarization

- The presence of this ECG pattern did not confer a higher risk for recurrent malignant ventricular arrhythmias.

- ST elevation 2 mm seems to be unusual even in athletes.
Manifestations of Increased Vagal Tone

- Sinus bradycardia,
- Prolonged PR interval
- Wenckebach phenomenon

are common in athletes as a result of the high resting vagal tone.
Uncommon findings

Interpretation of the Electrocardiogram of Young Athletes

Circulation. 2011
Q waves

The best test characteristics for Q waves in HCM were found with 3 mm in depth and/or 40 ms duration in at least 2 leads.
Conduction Delay

• All athletes with a QRS duration 120 ms should be referred for further evaluation

• Incomplete RBBB <120msec

• ASD ? ------- ECHO
Sailing
incomplete RBBB - left axis<-30
QRS Axis Deviation

• Right-axis deviation prevalence 20%

• Left-axis deviation prevalence 8%

• **should not trigger further evaluation** unless there is a history of pulmonary disease or systemic hypertension.

• We recommend an acceptable range of between -30 and 115 degrees for isolated axis deviation.
Right Ventricular Hypertrophy

- R wave 7 mm in V1,
- R/S ratio 1 in V1
- sum of R wave in V1 and S wave in V5/6 10.5 mm (Sokolow-Lyon).

Additional findings are necessary to elicit further evaluation

- right atrial abnormalities (RAA),
- T-wave inversion in V2/3,
- and/or right-axis deviation
Atrial Abnormalities

1. **RAA** >2.5 mm in any lead

2. **LAA**
   - A negative component of the P wave in V1 or V2 of 40 ms duration and 1 mm amplitude
   - Total P-wave duration of 120 ms

- We recommend that in collegiate and adult athletes, atrial abnormalities lead to secondary investigation
QT Abnormalities (Long and Short)
SYNCHRONIZED SWIMMING
## TABLE . DIAGNOSIS OF LQTS

<table>
<thead>
<tr>
<th>ECG</th>
<th>Βαθμοί</th>
</tr>
</thead>
<tbody>
<tr>
<td>• QTc</td>
<td></td>
</tr>
<tr>
<td>&gt;480ms</td>
<td>3</td>
</tr>
<tr>
<td>460-470ms</td>
<td>2</td>
</tr>
<tr>
<td>450ms (για άνδρες)</td>
<td>1</td>
</tr>
<tr>
<td>• VT (torsades de pointes)</td>
<td>2</td>
</tr>
<tr>
<td>• T WAVES ABNORMALITIES</td>
<td>1</td>
</tr>
<tr>
<td>• HAMPED T WAVES IN V1-V3</td>
<td>1</td>
</tr>
<tr>
<td>• BRADYCARDIA</td>
<td>0.5</td>
</tr>
</tbody>
</table>

### MEDICAL HISTORY

| • SYNCOPAL EPISODE       |       |
| - stress                | 2     |
| - NO stress              | 1     |
| • CONGENITAL HEARING PROBLEMS | 0.5 |

### Οικογενειακό ιστορικό

| • LQTS IN THE FAMILY     | 1     |
| • UNKNOWN CAUSE SCD IN A RELATIVE <30 YEARS OLD | 0.5 |
LQTS

- >4 POINTS = POSSIBILITY IS HIGH
- 2 - 3 POINTS = MEDIUM
- <1 POINT = LOW
LQTS

- **BAZETT FORMULA**
- Less reliable at low or very high HR
- Bifid appearance should be taken into account

- Men athletes QTc > 470
- Female athletes QTc > 480 msec
SQTS

- QTc < 340 msec
- QTc < 320 msec very rare
LQTS, SQTS

- exclusion of secondary causes of LQTS, SQTS
- 4-generation family pedigree,
- exercise or medication stress,
- extended rhythm monitoring,
- LYING AND STANDING ECG
- consideration of genetic testing.

Interpretation of the Electrocardiogram of Young Athletes
Circulation. 2011
Brugada-Like ECG Abnormalities
Brugada syndrome
### Diagnostic Criteria for BRS

**Major criteria**

1. Presence of the ECG marker of Brugada syndrome in patients with structurally normal heart
2. Appearance of the ECG marker of Brugada syndrome after administration of sodium channel blockers

**Minor criteria**

1. Family history of sudden cardiac death
2. Syncope of unknown origin
3. Documented episodes of ventricular tachycardia/ventricular fibrillation
4. Positive programmed electrocardiostimulation test on ventricular tachycardia/ventricular fibrillation
5. Genetic mutations of ion channels (*to be defined*)

*ECG = electrocardiographic.*
Ventricular Preexcitation

- Because athletes are at higher risk for AF than the general population,
- There is greater concern for associated sudden death.

- ECHO- EPS : ESC 2010
T-Wave Inversion

- T-wave inversion (TWI) has similar prevalence among athletes and sedentary controls, suggesting that it is not a training-related phenomenon. Indeed, Pelliccia et al showed that TWI in the presence of normal imaging may be a harbinger of a future cardiomyopathic disease.

- In athletes not of African origin, TWI 1 mm in leads other than III, aVR, and V1/2 should lead to secondary evaluation.
LONG DISTANCE RUNNING
INVERTED T WAVES V1-V4,
SOKOLOW, P-R: 220
Repolarisation Anomalies in Athletes

Physiological manifestation of athlete’s heart

Association with disease phenotypes and arrhythmogenic SCD
Repolarisation Anomalies

NORMAL
ST-segment elevation
Tall T waves

POSSIBLY NORMAL
Prolonged QT interval < 480 msec
Brugada ECG pattern (type 2 and 3)
Terminal notch on the downstroke to the QRS

ABNORMAL
ST-segment depression
T wave inversion
16 years
Male
Caucasion

Vent. rate 68 bpm
PR interval 122 ms
QRS duration 98 ms
QT/QTc 424/450 ms
P-H axis 26 74 236

*** Age and gender specific ECG analysis ***
Normal sinus rhythm
ST elevation consider anterior injury or acute infarct
** ** ACUTE MI ** **
Abnormal ECG

Technician:
Test ind:

Referred by:
Unconfirmed
ST Depression

- ST depression is rare in athletes and always deserves further workup.
Hypertrophic Cardiomyopathy

- Hypertrophy
- Myocardial Dissaray
- Diastolic Dysfunction
- Sarcomeric Disease
- Genetic Disease
Familial cardiac disease
**SUBCLINICAL CARDIOMYOPATHY OR ATHLETIC HEART SYNDROME**

- **ATHLETE FOOT BALL**
- Age 16-17 y old
- asymptomatic
- o/e = unremarkable
- Medical history
- Family history
Arrhythmogenic Right Ventricular Cardiomyopathy
NEW CLINICAL DIAGNOSTIC CRITERIA

Circulation 2010

1. VE’S VT (LBBB)
   - VT (LBBB-LEFT AXIS)
   - VT (LBBB-RIGHT AXIS) KES>500/24h

2. REPOLARIZATION
   - INVERTED T WAVES: V1-V3 (>14ετών)
   - INVERTED T WAVES: V1-V2 (>14ετών)
   - E WAVE ( POST ECXITATION )

3. POST ECXITATION
   - TAD≥55ms - LP(QRS≥114 LAS≥38 RMS<20)
   - AKINESIA/DYSKINESIA/ANEURYSM+ RVOT≥32mm
   - AKINESIA/ DYSKINESIA+ RVOT≥29mm

4. STRUCTURAL /FUNCTIONAL
   - ARVC IN THE FAMILY
   - Probable ARVC – SCD<35 ετών

5. FAMILIAL DISEASE

ARVC: 2M ἦ 1M+2E ἦ 4E

MAJOR
MINOR
Ventricular Extrasystoles and Supraventricular Arrhythmia

- AF/Afl
- SV tachy
- Complete heart block
- > 2 VE’S on ECG

- IF SUBSTRATE NORMAL SHULD NOT BE LIMITED INCLUDING LONE AF
Athlete’s Heart or HCM

- Bizarre patterns of LVH
- LV cavity > 54 mm
+ LA > 50 mm
+ LV outflow obstruction
+ Impaired diastolic function
- Isolated Sokolow-Lyon LVH
+ ST depression/Deep T wave inversion
+ Female gender
- Absence of HCM in first degree rels
- Peak VO2 > 50 ml/kg/min
Role of ECG in Differentiating Physiological Adaptation from ARVC

Symptoms
- Family history
- Impaired RV function
- Impaired LV function
- Epsilon waves
- VT

Asymptomatic
- Voltage criteria for LVH on ECG
- LV dilatation and preserved function
- Good RV function

ARVC
- RV dilatation, incomplete RBBB
- Inverted T waves V1-V3
- Ventricular extrasytoles of LBBB morphology

Athlete’s Heart
Role of ECG in Differentiating Physiological Adaptation from Dilated Cardiomyopathy

Symptoms
- Family history
- Low E'
- Low Es
- Abnormal ECG
- Low peak VO2

Asymptomatic
- Exercise echo shows excellent LV function
- Isolated Sokolow Lyon voltage criterion for LVH
- High peak VO2

DCM

Athlete's Heart

Enlarged LV Cavity

Low Ejection Fraction

Low peak VO2
FEMALES

• Unlike male athletes who most commonly show abnormal ECG patterns, female athletes usually have normal or virtually normal ECGs.

EUROPEAN RECOMMENDATIONS
Eur Heart J 2010
Black athletes

- Black athletes have more prevalent and pronounced ECG changes,
- including voltage criteria for left ventricular hypertrophy and
- early repolarization changes
- which reflect the race-related greater magnitude of left ventricular hypertrophy and/or increased vagal sensitivity.

EUROPEAN RECOMMENDATIONS
Eur Heart J 2010
ECG in Black Athletes

**Physiology**
- ST segment elevation
- Voltage LVH
- Inverted T waves in V1-V4

**Pathology**
- Deep T wave inversions in contiguous inferior leads
- Deep T wave inversions V5-V6
- ST segment depression
- Pathological Q waves
ECG AND TYPE OF SPORTS
EUROPEAN RECOMMENDATIONS
Eur Heart J 2010

• Level and duration of training or competition, aerobic capacity and type of sports activity play a significant role as well.

Participation in sports that require high endurance, such as
• cycling,
• cross-country skiing and
• rowing/canoeing,
• Marathon runners

• has been shown to be significantly associated with a higher rate and greater extent of physiologic ECG changes.
FAMILY HISTORY

• In the presence of a positive family history, symptoms or abnormal physical findings, otherwise physiologic ECG changes may become clinically relevant and require clinical work-up to exclude a pathologic basis

EUROPEAN RECOMMENDATIONS
Eur Heart J 2010
<table>
<thead>
<tr>
<th>ECG Abnormality</th>
<th>Criteria for further evaluation</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q waves</td>
<td>&gt;3 mm in depth or &gt;40 ms duration in any lead except III, aVR, aVL and V1</td>
<td><img src="image" alt="Q waves" /></td>
</tr>
<tr>
<td>ST depression</td>
<td>&gt;0.5 mm below PR isoelectric line between J-junction and beginning of T waves in V4, V5, V6, I, aVL</td>
<td><img src="image" alt="ST depression" /></td>
</tr>
<tr>
<td></td>
<td>&gt;1 mm in any lead</td>
<td></td>
</tr>
<tr>
<td>T wave inversion</td>
<td>&gt;1 mm in leads other than III, aVR and V1 (except V2 and V3 in women &lt;25 years)</td>
<td><img src="image" alt="T wave inversion" /></td>
</tr>
</tbody>
</table>
| Atrial abnormalities          | Right: P wave amplitude >2.5 mm  
Left: i) Negative portion of P wave in V1, V2 of >40 ms duration and 1 mm in depth; or ii) total P wave duration >120 ms | ![Atrial abnormalities](image) |
| Right ventricular hypertrophy | >30 years: i) R wave >7 mm in V1; or ii) R/S ratio >1 in V1; or iii) sum of R wave in V1 and S wave in V5 or V6 >10.5 mm  
<30 years: above plus right atrial enlargement, T wave inversion in V2, V3, or right axis deviation >115° | ![Right ventricular hypertrophy](image) |
<table>
<thead>
<tr>
<th>Condition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>LBBB, RBBB, IVCD</td>
<td>Any QRS &gt;120 ms</td>
</tr>
<tr>
<td>QRS axis deviation</td>
<td>More leftward than -30°, More rightward than 115°</td>
</tr>
<tr>
<td>QTC interval</td>
<td>&gt;470 ms in males, &gt;480 ms in females, &lt;340 ms in any athlete</td>
</tr>
<tr>
<td>Brugada pattern</td>
<td>Presence of Type 1 pattern: coved ST segment in V1 and V2 gradually descending into inverted T wave</td>
</tr>
<tr>
<td>Pre-Excitation</td>
<td>Delta wave and PR interval &lt;120 ms</td>
</tr>
<tr>
<td>Ventricular extrasystoles, heart block, and supraventricular arrhythmia</td>
<td>Atrial fibrillation/flutter, supraventricular tachycardia, complete heart block or ≥2 PVCs in one 12 lead ECG</td>
</tr>
</tbody>
</table>

RBBB – right bundle branch block; LBBB – left bundle branch block, IVCD – intra-ventricular conduction delay, PVC – premature ventricular contraction. Measurements are by visual analysis.
ECG IN ATHLETES

• To reduce the financial and psychological burden of false-positive ECGs, interpretation should be carried out using athlete-specific criteria.
PREVENTION OF SUDDEN DEATH IN THE YOUNG

• ECG is very important clinical tool.
• We must know what we are looking for…

• CHALLENGE

– training
ΜΟΝΑΔΑ ΚΛΗΡΟΝΟΜΙΚΩΝ
ΚΑΡΔΙΑΓΓΕΙΑΚΩΝ ΠΑΘΗΣΕΩΝ

ΕΚΚΑΝ
ΔΗΜΙΟΥΡΓΙΑ ΚΑΓΙΩΝ ΑΘΗΝΑΣ ΚΑΙ ΝΕΟΥ