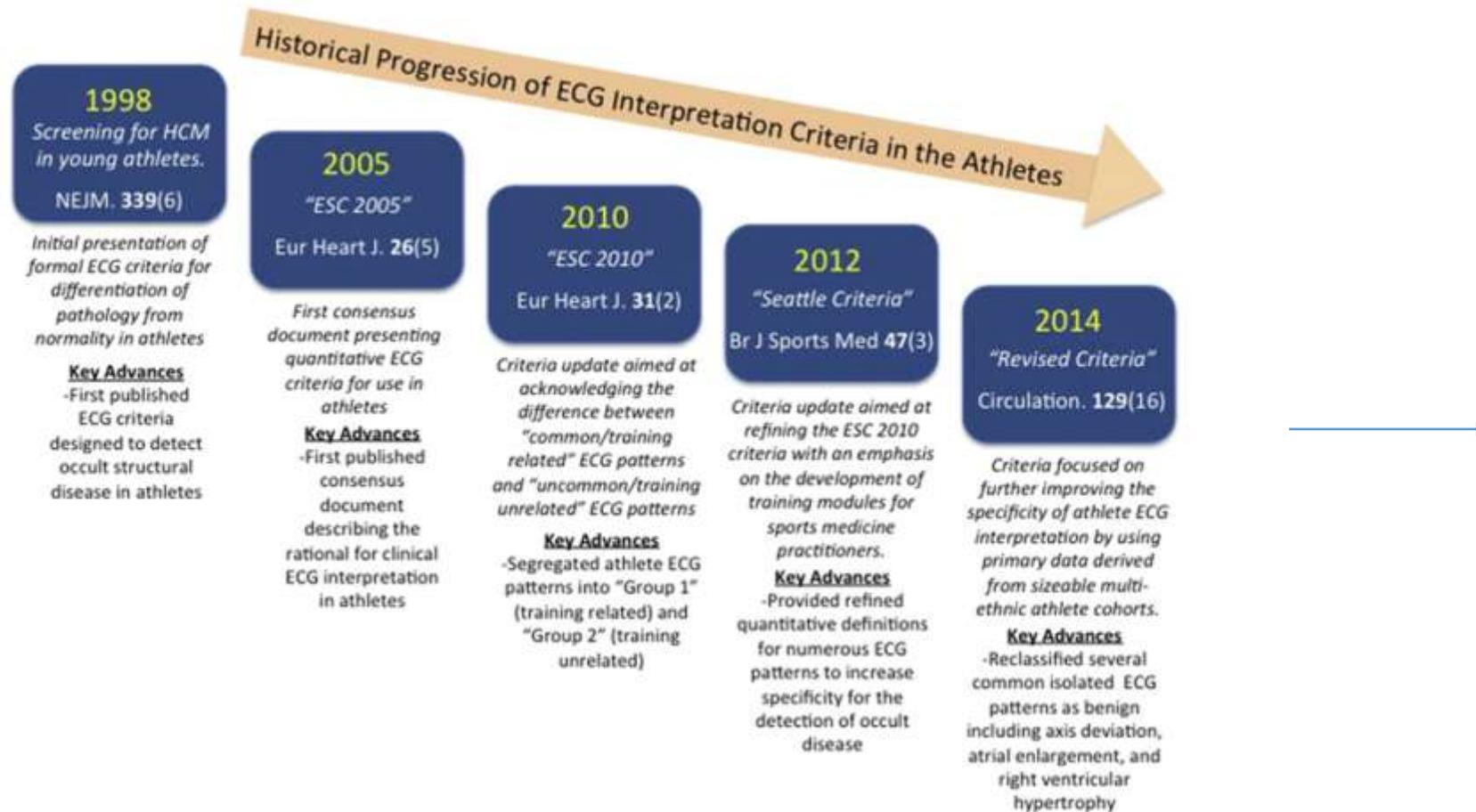**Dott. Alessandro Zorzi**
Dipartimento Scienze Cardiogiche, Toraciche,
Vascolari e Sanità pubblica
Università di Padova

L'Elettrocardiogramma dell'atleta

Incontro AIAC-FMSI
Rovereto 1 giugno 2019

Alessandro Zorzi, MD, PhD, FESC
University of Padova, Italy
alessandro.zorzi@unipd.it

Historical Progression of ECG Interpretation Criteria in the Athletes

1998
Screening for HCM in young athletes.
NEJM. 339(6)

Initial presentation of formal ECG criteria for differentiation of pathology from normality in athletes

Key Advances
-First published ECG criteria designed to detect occult structural disease in athletes

2005
"ESC 2005"
Eur Heart J. 26(5)

First consensus document presenting quantitative ECG criteria for use in athletes

Key Advances
-First published consensus document describing the rational for clinical ECG interpretation in athletes

2010
"ESC 2010"
Eur Heart J. 31(2)

Criteria update aimed at acknowledging the difference between "common/training related" ECG patterns and "uncommon/training unrelated" ECG patterns

Key Advances
-Segregated athlete ECG patterns into "Group 1" (training related) and "Group 2" (training unrelated)

2012
"Seattle Criteria"
Br J Sports Med 47(3)

Criteria update aimed at refining the ESC 2010 criteria with an emphasis on the development of training modules for sports medicine practitioners.

Key Advances
-Provided refined quantitative definitions for numerous ECG patterns to increase specificity for the detection of occult disease

2014
"Revised Criteria"
Circulation. 129(16)

Criteria focused on further improving the specificity of athlete ECG interpretation by using primary data derived from sizeable multi-ethnic athlete cohorts.

Key Advances
-Reclassified several common isolated ECG patterns as benign including axis deviation, atrial enlargement, and right ventricular hypertrophy

INTERNATIONAL
CRITERIA
2017

Baggish AL, Journal of Electrocardiology 2015; 48:324–328

The New England
Journal of Medicine

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VOLUME 339   AUGUST 6, 1998   NUMBER 6

SCREENING FOR HYPERTROPHIC CARDIOMYOPATHY IN YOUNG ATHLETES

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

TABLE 1. CRITERIA FOR A POSITIVE 12-LEAD ELECTROCARDIOGRAM.*

P wave

Left atrial enlargement: negative portion of the P wave in lead V_1 ≥0.1 mV in depth and ≥0.04 sec in duration

Right atrial enlargement: peaked P wave in leads II and III or V_1 ≥0.25 mV in amplitude

QRS complex

Frontal-plane axis deviation: right ≥+120 degrees or left −30 degrees to −90 degrees

Increased voltage: amplitude of R or S wave in a standard lead ≥2 mV, S wave in lead V_1 or V_2 ≥3 mV, or R wave in lead V_5 or V_6 ≥3 mV

Abnormal Q waves ≥0.04 sec in duration or ≥25 percent of the height of the ensuing R wave, or QS pattern in two or more leads

Right or left bundle-branch block with QRS duration ≥0.12 sec

R or R' wave in lead V_1 ≥0.5 mV in amplitude and R:S ratio ≥1

ST segment, T waves, and QT interval

ST-segment depression or T-wave flattening or inversion in two or more leads

Prolongation of QT interval corrected for the heart rate >0.44 sec

Rhythm and conduction abnormalities

Premature ventricular beats or more severe ventricular arrhythmia

Supraventricular tachycardia, atrial flutter, or atrial fibrillation

Short PR interval (<0.12 sec) with or without delta wave

Sinus bradycardia with resting heart rate ≤40 beats per minute and increasing to <100 beats per minute during limited exercise testing

First-degree (PR ≥0.21 sec, not shortening with hyperventilation or limited exercise testing), second-degree, or third-degree atrioventricular block

*The criteria are from Friedman,[17] Romhilt and Estes,[18] Morris et al.,[19] and Savage et al.[20]

TABLE 1. Distribution of ECG Abnormalities in 1005 Trained Athletes

Distinctly Abnormal ECG (n=145)		Mildly Abnormal ECG (n=257)		ECG Normal or With Minor Alterations (n=603)	
Parameter	n (%)	Parameter	n (%)	Parameter	n (%)
R or S wave ≥35 mm	92 (63)	R or S wave 30–34 mm	141 (55)	R or S wave 25–29 mm	170 (28)
Negative T wave	27 (19)	Flat/tall T wave	59 (23)	J-junction elevation	144 (24)
Q wave ≥4 mm	17 (12)	Q wave 2–3 mm	69 (27)	Incomplete RBBB	122 (20)
LAD	11 (8)	LAE	9 (4)	PR interval >0.20 s	75 (12)
RAD	8 (6)	RAE	2 (0.8)		
WPW	3 (2)	Incomplete R wave progression V_1 to V_3	40 (16)	Sinus bradycardia <60 bpm	369 (61)
LBBB	2 (1)	PR interval ≤0.12 s	9 (4)		
		RBBB	2 (0.8)		

J-junction indicates early repolarization pattern; LAD, left axis deviation (≤−30°); LBBB, left bundle branch block; LAE, left atrial enlargement; Incomplete R wave progression V_1 to V_3, abnormal pattern of R wave progression in the anterior precordial leads V_1 to V_3; RAD, right axis deviation (≥110°); RAE, right atrial enlargement; RBBB, right bundle branch block; and WPW, Wolff-Parkinson-White pattern.

Pelliccia et al. Circulation. 2000;102:278-84

European Heart Journal
doi:10.1093/eurheartj/ehp473

ESC REPORT

Recommendations for interpretation of 12-lead electrocardiogram in the athlete

ANOMALIE COMUNI E CORRELATE ALL'ESERCIZIO	ANOMALIE NON COMUNI
Bradicardia sinusale	Blocco AV di 2° e 3° grado
Blocco AV di primo grado	Aritmie ventricolari
Ipertrofia ventricolare sinistra per criterio di voltaggio isolato	Ingrandimento atriale
Blocco incompleto di b. dx	Deviazione assiale sinistra/emiblocco anteriore sinistro
Ripolarizzazione precoce	Deviazione assiale destra/emiblocco anterore destro
	Ipertrofia ventricolare destra
	Ipertrofia ventricolare sinistra per criteri non di solo voltaggio
	Blocco di branca
	Onde Q patologiche
	Sottoslivellamento ST
	QT lungo o corto
	Aspetto "coved-type" (Brugada)
	Onde T negative

2010-2019

Alessandro Zorzi, MD, PhD, FESC
University of Padova, Italy
alessandro.zorzi@unipd.it

Children
N=2765

T-wave inversion
in ≥2 leads
N=158 (5.7%)

No T-wave inversion
N=2607 (94.3%)

T-wave inversion in
inferior leads
(II/aVF)
N=24 (0.9%)

T-wave inversion in
right precordial leads
(V1-V3)
N=131 (4.7%)

T-wave inversion in
lateral leads
(V4-V6 and/or I-aVL)
N=3 (0.1%)

Echocardiography

Echocardiography

Echocardiography

No cardiomyopathies

"definitive" ARVC (N=1) *
"borderline" ARVC (N=2)†

HCM (N=1) ‡
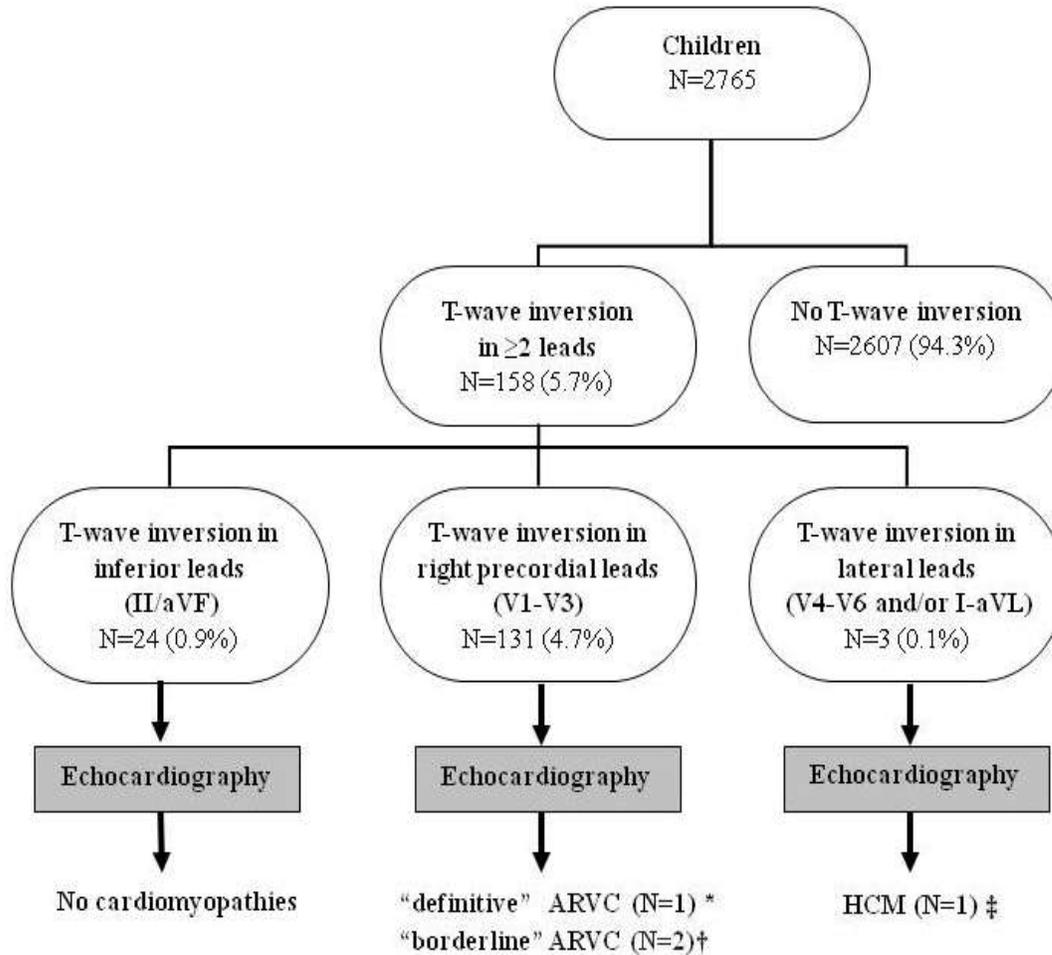
2,765 atleti tra 9 e 19 anni
158 con T negative (5.7%)

Di cui

154 (5.6%) falsi positivi
4 (0.1%) veri positivi

Migliore F, Zorzi A, et al; Circulation – 2012
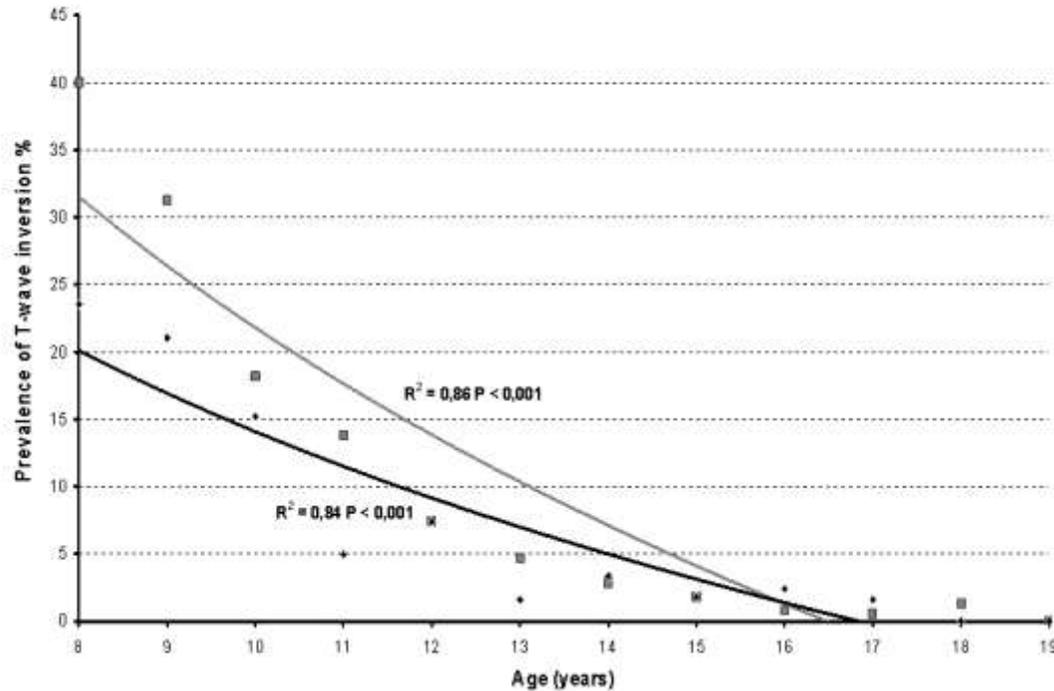
Variabile	Analisi monovariata			Analisi multivariata		
	OR	95% CI	P	OR	95% CI	P
Sviluppo puberale incompleto	6.5	4.2-9.9	<0.001	3.6	1.9-6.8	<0.001
Età	5.3	3.4-8.2	<0.001	1.7	0.9-3.3	0.1
Basso peso	2.4	3.2-1.7	<0.001	1.5	0.9-2.1	0.09
Sesso maschile	1.1	0.8-1.6	0.15	1.1	0.8-1.7	0.55

Escludendo i ragazzi prepuberi: prevalenza di T negative 1.6%
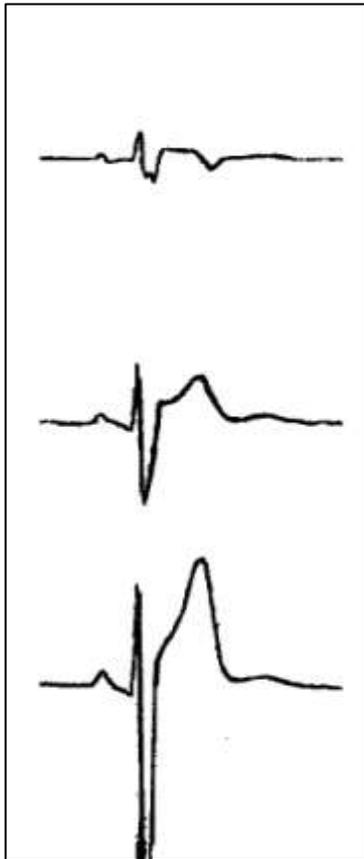
Migliore F, Zorzi A,et al; Circulation – 2012
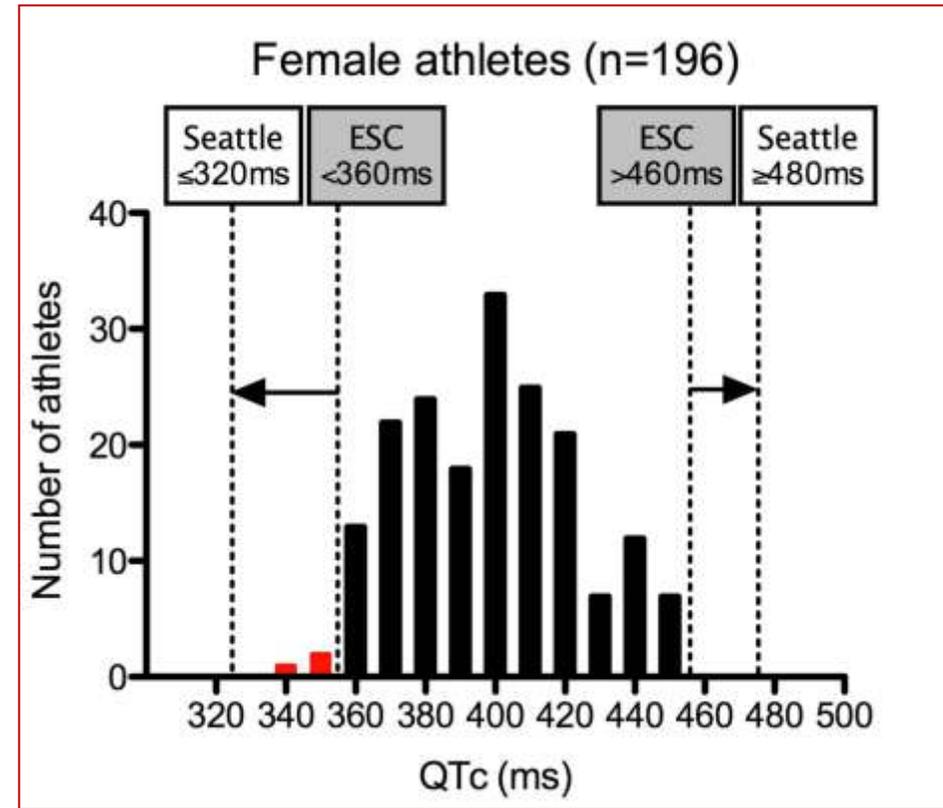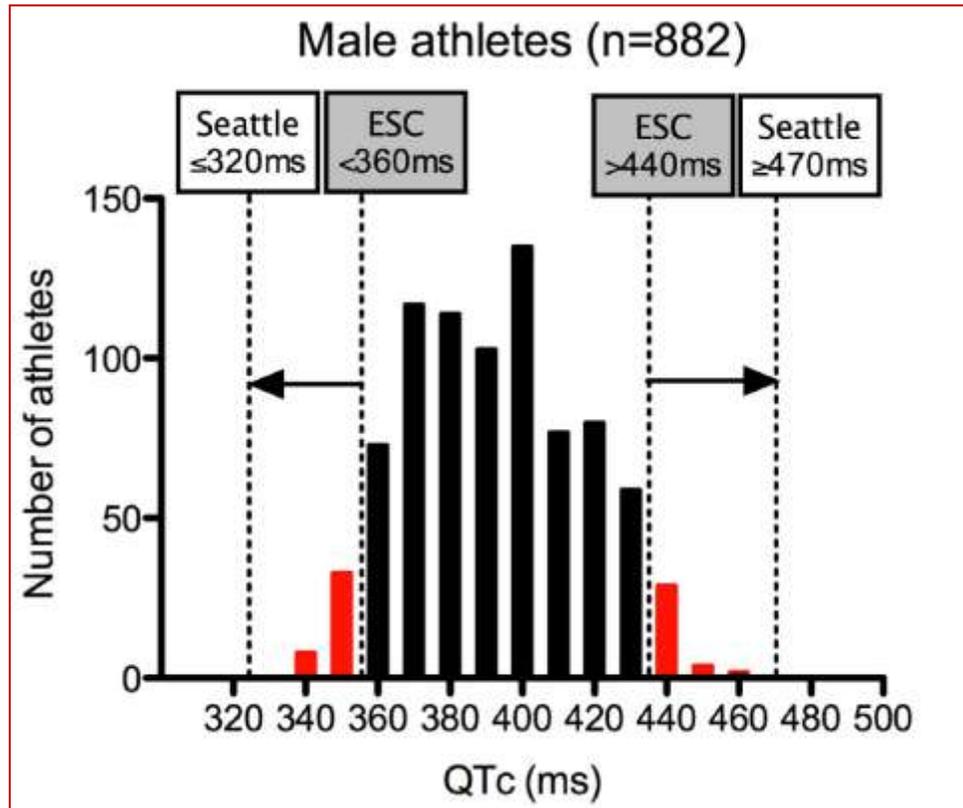
Brosnan et al. Br J Sports Med 2014;48:1144–1150

Alessandro Zorzi, MD, PhD, FESC
University of Padova, Italy
alessandro.zorzi@unipd.it

Black athlete

ESC criteria

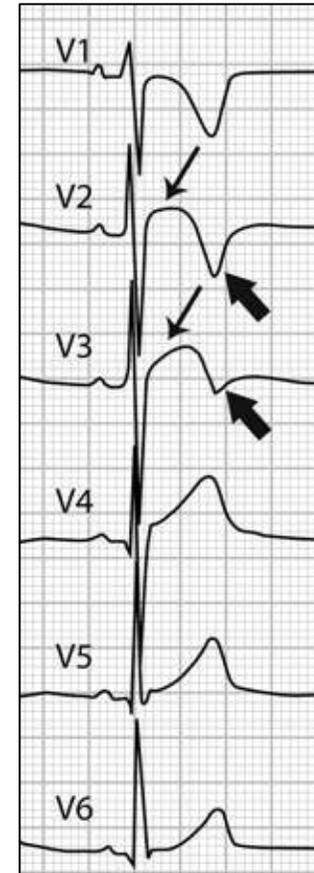# Varianti di ripolarizzazione precoce

Tipica degli **atleti caucasici**

Caratterizzata da sopraslivellamento del punto J e da tratto ST ascendente

L'onda T è positiva

Puo' raramente porre problemi di diagnosi differenziale con l'infarto

Tipica degli **atleti afro-caraibici**

Caratterizzata da sopraslivellamento del punto j e da tratto st "a conca" con inversione terminale dell'onda t

Pone problemi di *diagnosi differenziale* con:
- Sindrome di brugada
- T negative cardiomiopatiche

Differential Diagnosis Between Early Repolarization of Athlete's Heart and Coved-Type Brugada Electrocardiogram

Alessandro Zorzi, MD[a], Loira Leoni, MD, PhD[a], Fernando M. Di Paolo, MD[b], Ilaria Rigato, MD, PhD[a], Federico Migliore, MD, PhD[a], Barbara Bauce, MD, PhD[a], Antonio Pelliccia, MD[b], and Domenico Corrado, MD, PhD[a,*]
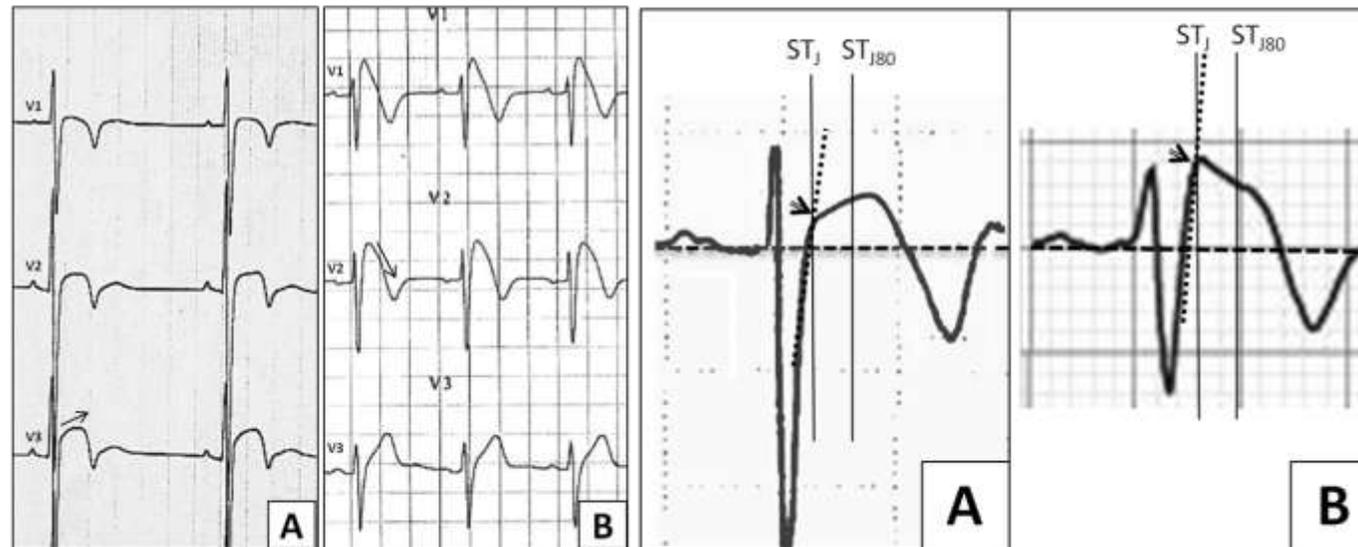
An up-sloping ST-segment configuration ($ST_J/ST_{80}<1$) showed a sensitivity of 97%, a specificity of 100% and a diagnostic accuracy of 98.7% for the diagnosis of ER.
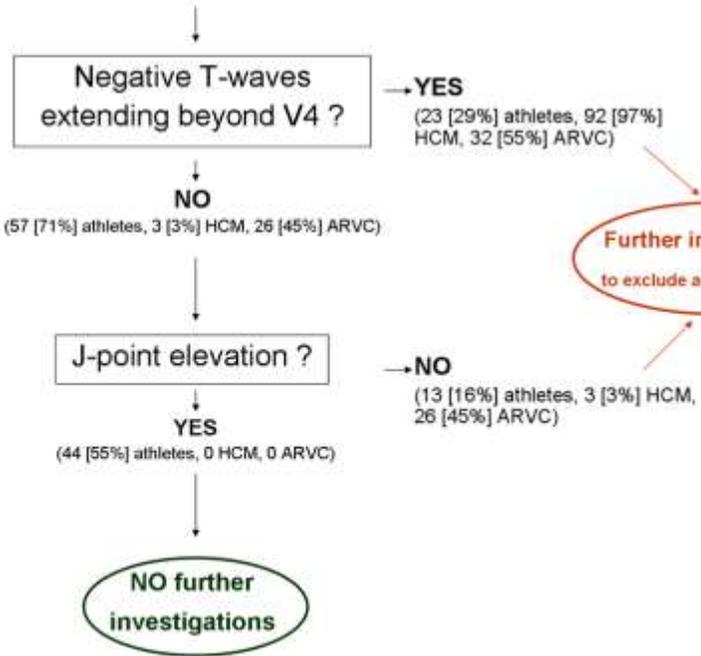
Electrocardiographic anterior T-wave inversion in athletes of different ethnicities: differential diagnosis between athlete's heart and cardiomyopathy

Chiara Calore[1][†], Alessandro Zorzi[1][†], Nabeel Sheikh[2][‡], Alberto Nese[1], Monica Facci[1], Aneil Malhotra[2], Abbas Zaidi[2], Maurizio Schiavon[3], Antonio Pelliccia[4], Sanjay Sharma[2][‡], and Domenico Corrado[1][‡][*]

Negative T-waves in V1-V4
(80 athletes, 95 HCM, 58 ARVC)

Negative T-waves extending beyond V4 ? → YES
(23 [29%] athletes, 92 [97%] HCM, 32 [55%] ARVC)

NO
(57 [71%] athletes, 3 [3%] HCM, 26 [45%] ARVC)

J-point elevation ? → NO
(13 [16%] athletes, 3 [3%] HCM, 26 [45%] ARVC)

YES
(44 [55%] athletes, 0 HCM, 0 ARVC)

Further investigations to exclude a cardiomyopathy

NO further investigations

ATHLETES

HCM

ARVC

Prevalenza di alterazioni della ripolarizzazione negli atleti black

Papadakis, et al; Eur Heart J 2011

Refined Criteria Training Related Normal Variants
Not Warranting Further Investigation*

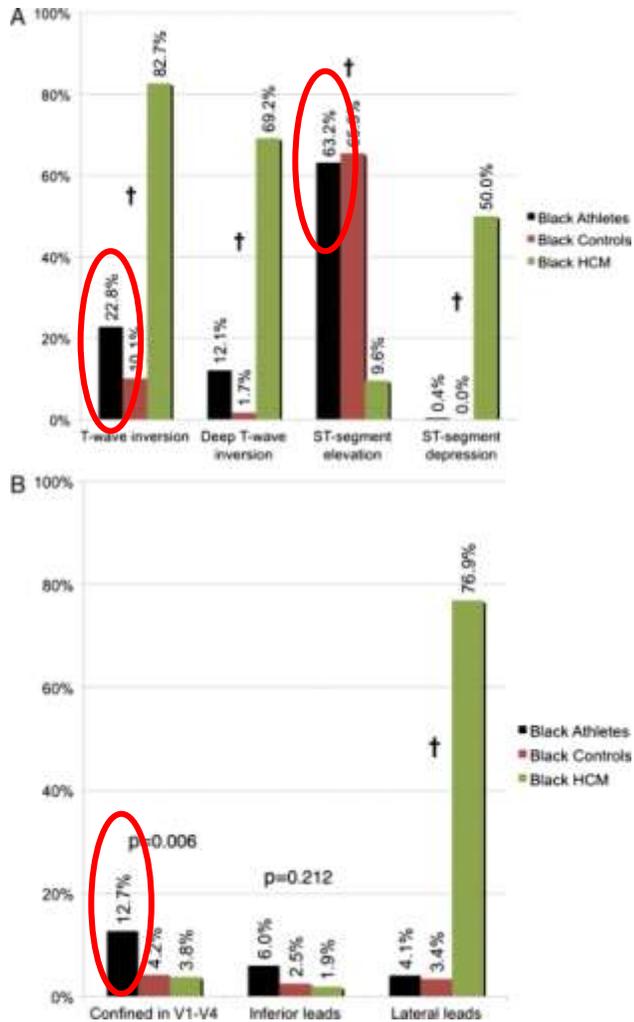- Sinus bradycardia
- First-degree AV block
- Incomplete RBBB
- Early repolarisation
- Isolated QRS voltage criteria for LVH

Refined Criteria Borderline Variants
Potentially Warranting Further Investigation

- Left atrial enlargement
- Right atrial enlargement
- Left axis deviation
- Right axis deviation
- Right ventricular hypertrophy
- TWI up to V4 in BAs†

†When preceded by characteristic convex ST-segment elevation.

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 ms in males ≥480 ms in females
- Brugada-like ER
- Atrial or vent. arrhythmias
- ≥2 PVCs per 10 sec tracing

If present in ISOLATION*
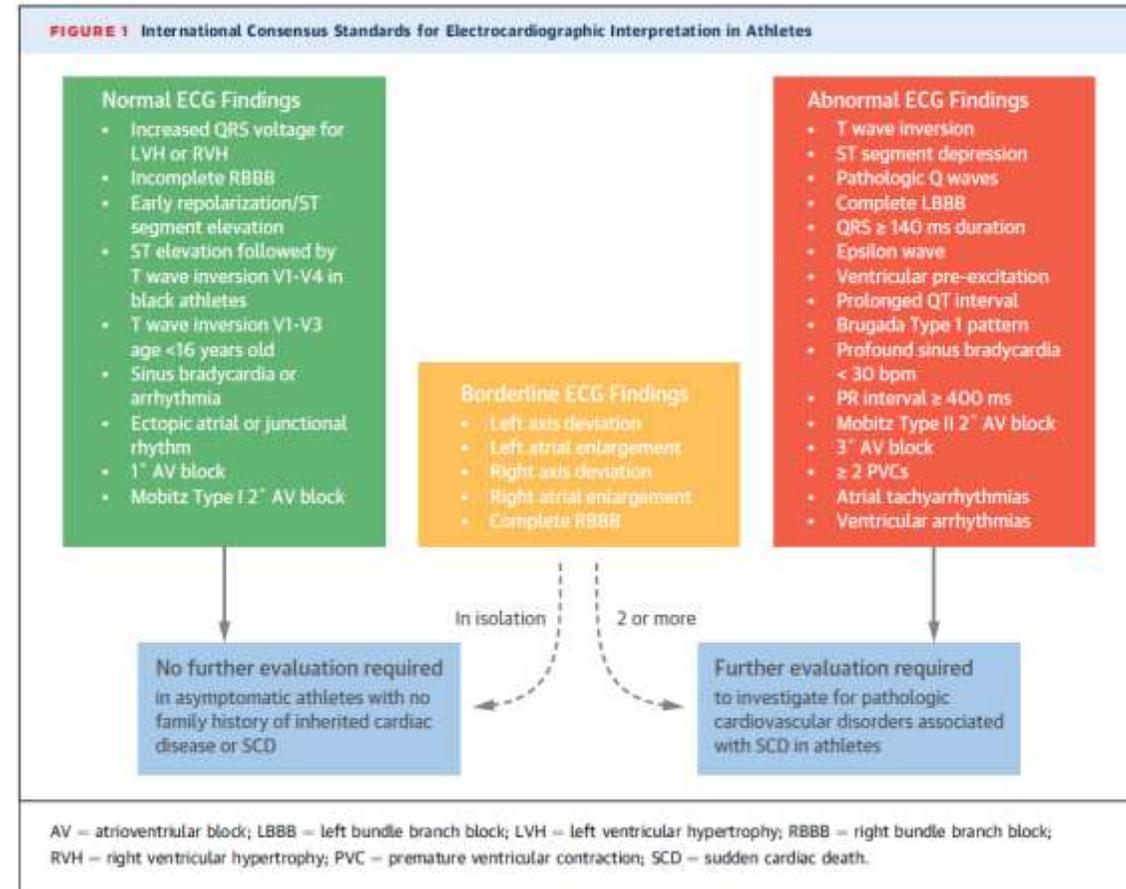
If TWO OR MORE present

Sheikh, et al; Circulation 2014

Sheikh, et al; Circulation 2014

International Recommendations for Electrocardiographic Interpretation in Athletes

FIGURE 1 International Consensus Standards for Electrocardiographic Interpretation in Athletes

Normal ECG Findings
- Increased QRS voltage for LVH or RVH
- Incomplete RBBB
- Early repolarization/ST segment elevation
- ST elevation followed by T wave inversion V1-V4 in black athletes
- T wave inversion V1-V3 age <16 years old
- Sinus bradycardia or arrhythmia
- Ectopic atrial or junctional rhythm
- 1° AV block
- Mobitz Type I 2° AV block

Borderline ECG Findings
- Left axis deviation
- Left atrial enlargement
- Right axis deviation
- Right atrial enlargement
- Complete RBBB

Abnormal ECG Findings
- T wave inversion
- ST segment depression
- Pathologic Q waves
- Complete LBBB
- QRS ≥ 140 ms duration
- Epsilon wave
- Ventricular pre-excitation
- Prolonged QT interval
- Brugada Type 1 pattern
- Profound sinus bradycardia < 30 bpm
- PR interval ≥ 400 ms
- Mobitz Type II 2° AV block
- 3° AV block
- ≥ 2 PVCs
- Atrial tachyarrhythmias
- Ventricular arrhythmias

In isolation / 2 or more

No further evaluation required in asymptomatic athletes with no family history of inherited cardiac disease or SCD

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

AV = atrioventricular block; LBBB = left bundle branch block; LVH = left ventricular hypertrophy; RBBB = right bundle branch block; RVH = right ventricular hypertrophy; PVC = premature ventricular contraction; SCD = sudden cardiac death.

Sharma S, et al. J Am Coll Cardiol 2017

E per gli atleti caucasici i nuovi criteri vanno ancora bene?

Confronto tra ECG di HCM e atleti: 2017 International criteria vs 2010 ESC Criteria

Table 1 ECG findings in patients with hypertrophic cardiomyopathy (HCM) and athletes

	HCM (n=200)	Athletes (n=563)	p Value
Group 1 (ESC 2010 normal, International 2017 normal)	9 (4.5)	489 (86.9)	<0.001
Normal ECG	8 (4)	321 (57.0.)	<0.001
Isolated voltage criteria for LVH	1 (0.5)	168 (29.8)	<0.001
Group 2 (ESC 2010 abnormal, International 2017 normal)	5 (2.5)	51 (9.1)	<0.001
Q-wave≥4 mm but<0.04 s and <1/4 of the R-wave	1 (0.5)	22 (3.9)	0.01
LAE in isolation	3 (1.5)	24 (4.3)	0.08
LAD in isolation	1 (0.5)	5 (0.9)	1.0
Group 3 (ESC 2010 abnormal, International 2017 abnormal)	186 (93.0)	23 (4.1)	<0.001
ST-segment depression	118 (59.0)	0	<0.001
LAE and LAD in association	3 (1.5)	2 (0.4)	0.12
Q-wave>0.04 s or>1/4 of the R-wave	57 (28.5)	0	<0.001
T-wave inversion	141 (70.5)	21 (3.9)	<0.001
Anterior T-wave inversion confined to V1–V4 and preceded by J-point elevation	0	13 (2.3)	0.03
Other T-wave inversion	141 (70.5)	8 (1.4)	<0.001
Left bundle branch block	12 (6)	0	<0.001

ESC, European Society of Cardiology; HCM, hypertrophic cardiomyopathy; LAD, left axis deviation; LAE, left atrial enlargement.; LVH, left ventricular hypertrophy.
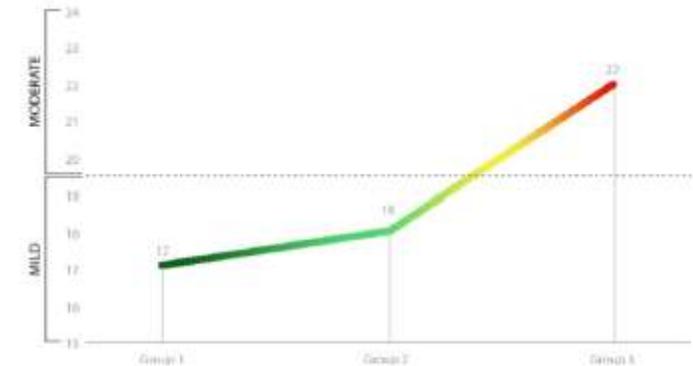
Figure 2 Mean maximal left ventricular wall thickness according to ECG pattern in patients with hypertrophic cardiomyopathy. Patients with group 1 and group 2 ECG patterns showed significantly lower maximal left ventricular wall thickness compared with group 3 patients. On the other hand, there was no statistically significant differences between group 1 and 2 patients.

Zorzi A, et al. Br J Sports Med 2017

Confronto tra ECG di ARVC e atleti con T negative anteriori

	ARVC with ATWI (n = 82)	Controls with ATWI (n = 129)	P-value
Age (years)	39 ± 16	23 ± 6	<0.001
Males, n (%)	54 (66)	57 (44)	0.003
White, n (%)	79 (96)	108 (84)	0.01
SR, n (%)	81 (99)	129 (100)	0.99
Heart rate (b.p.m.)	64 ± 13	63 ± 14	0.61
QRS duration (ms), n (%)	103 ± 18	93 ± 11	<0.001
>100	37 (45)	32 (25)	0.004
>120	9 (11)	3 (2)	0.01
RBBB, n (%)	6 (7)	0	0.09
Absence of J-point elevation, n (%)	80 (98)	98 (76)	<0.001
Anterior TWI, n (%)			
TWI limited to V1–V2	13 (16)	42 (32)	<0.001
TWI limited to V1–V3	16 (19)	55 (43)	<0.001
TWI limited to V1–V4	53 (65)	32 (25)	<0.001
Deep anterior TWI, n (%)	60 (73)	34 (26)	<0.001
QRS V2/V5 > 1.2, n (%)	32 (39)	19 (15)	<0.001
Prolonged S wave in V2*, n (%)	23 (28)	0	<0.001
Low voltages, n (%)	12 (15)	5 (4)	0.01
Ventricular ectopic beats ≥1, n (%)	12 (15)	3 (2)	<0.001
Epsilon waves, n (%)	6 (7)	0	0.009
LAD, n (%)	7 (9)	2 (2)	0.04

J-point elevation + TWI solo in V1-V4: 1/82 ARVC patients
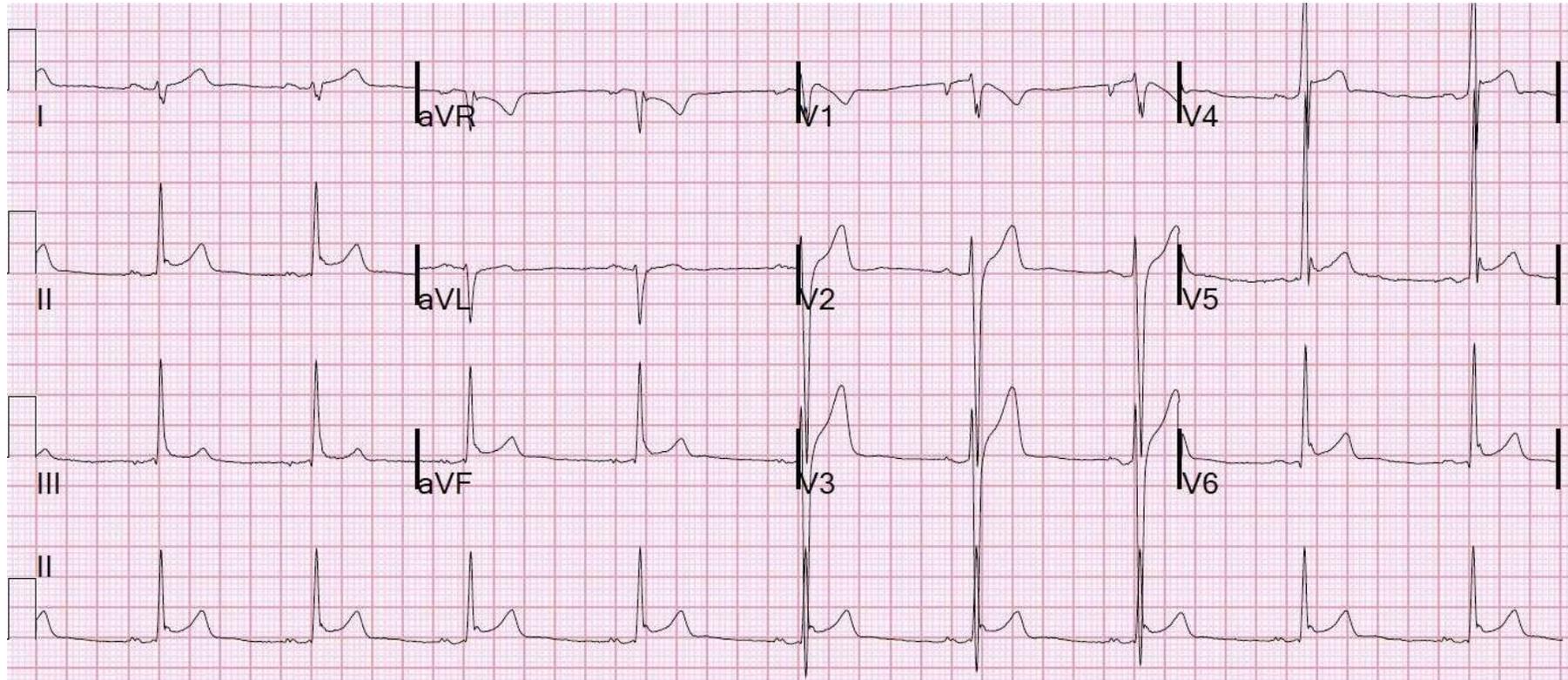
Finocchiaro G, et al. Europace 2019

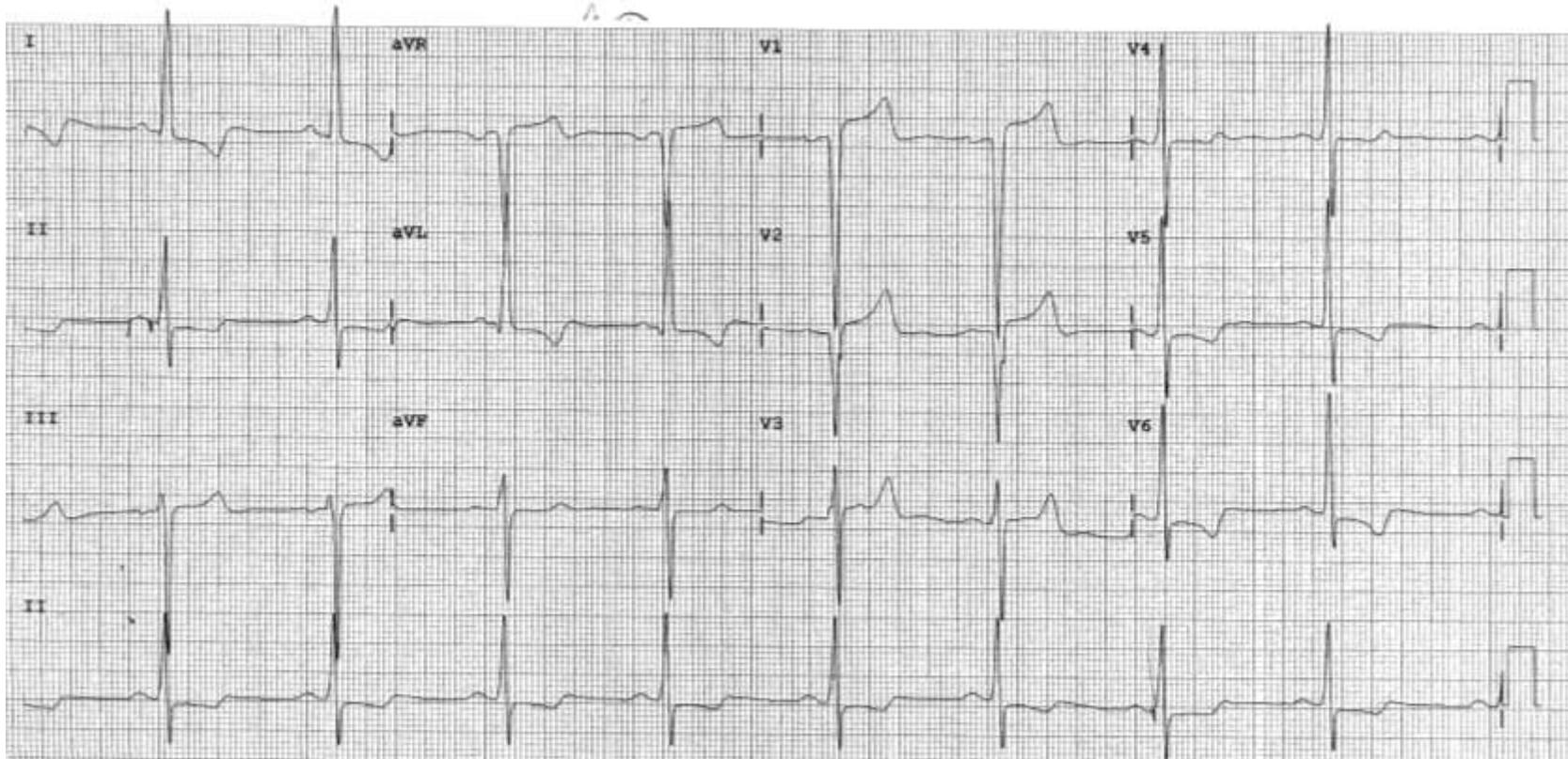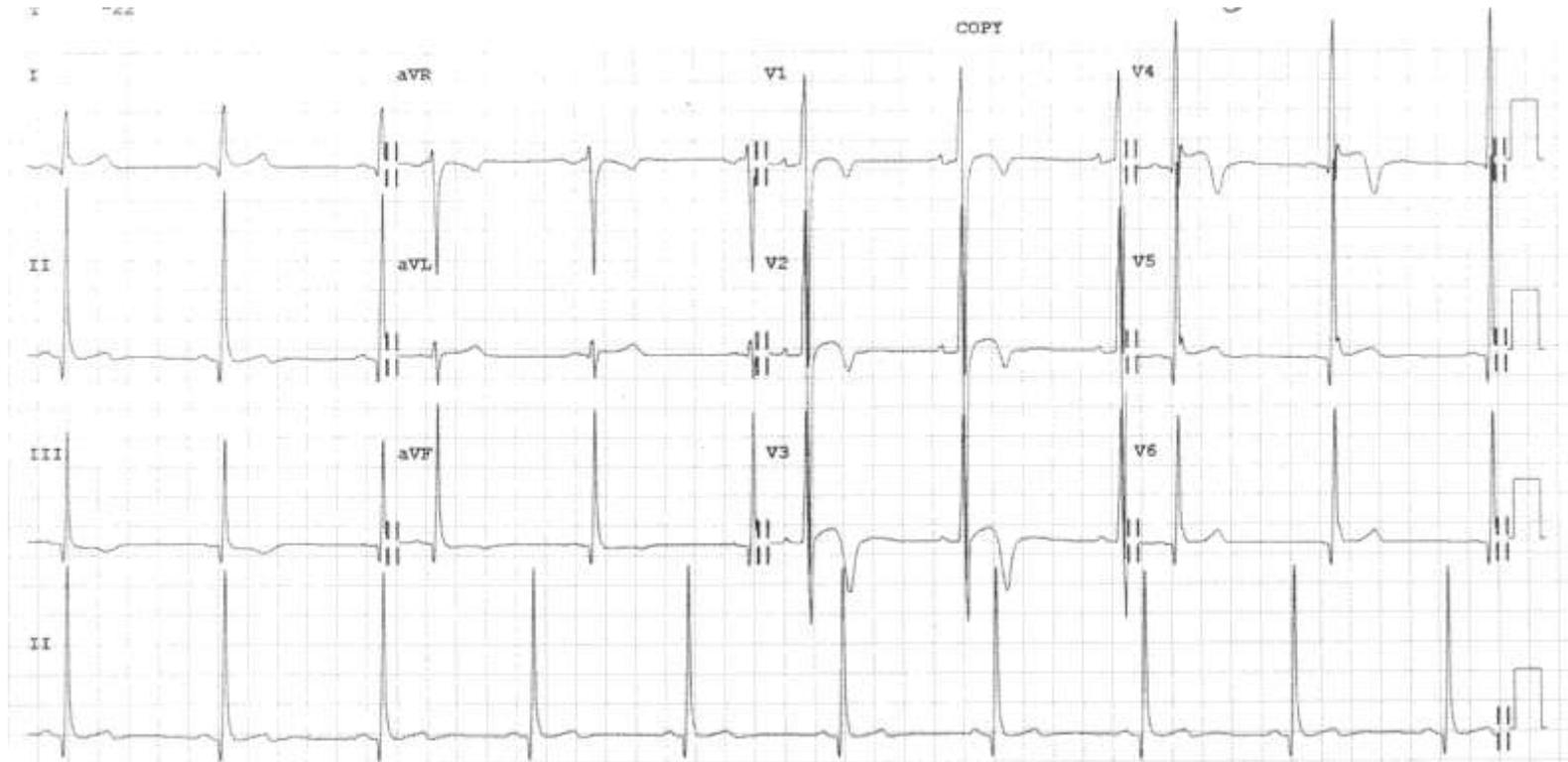Protocolli cardiologici per il giudizio di idoneità allo sport agonistico 2017

Anomalie ECG dell'atleta

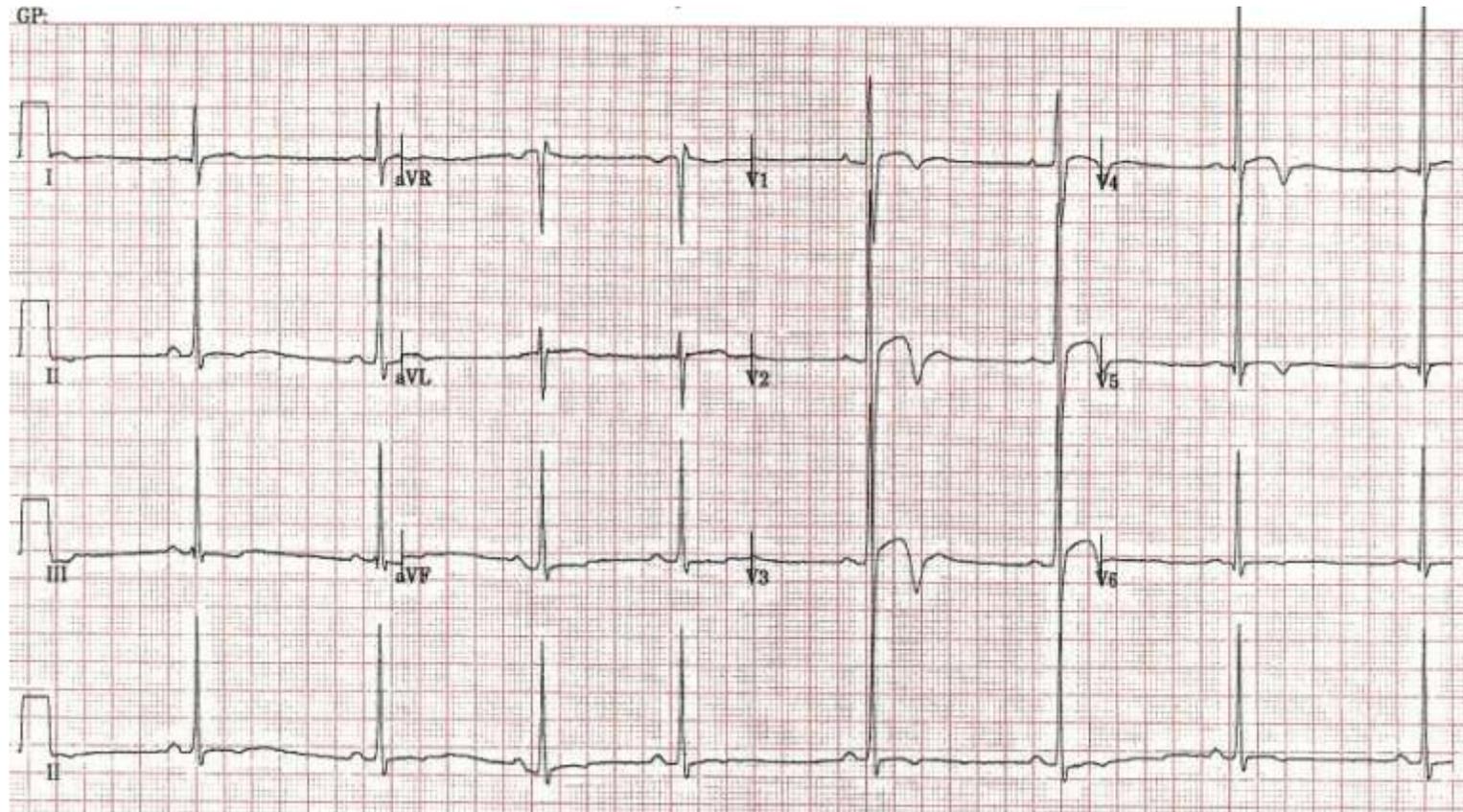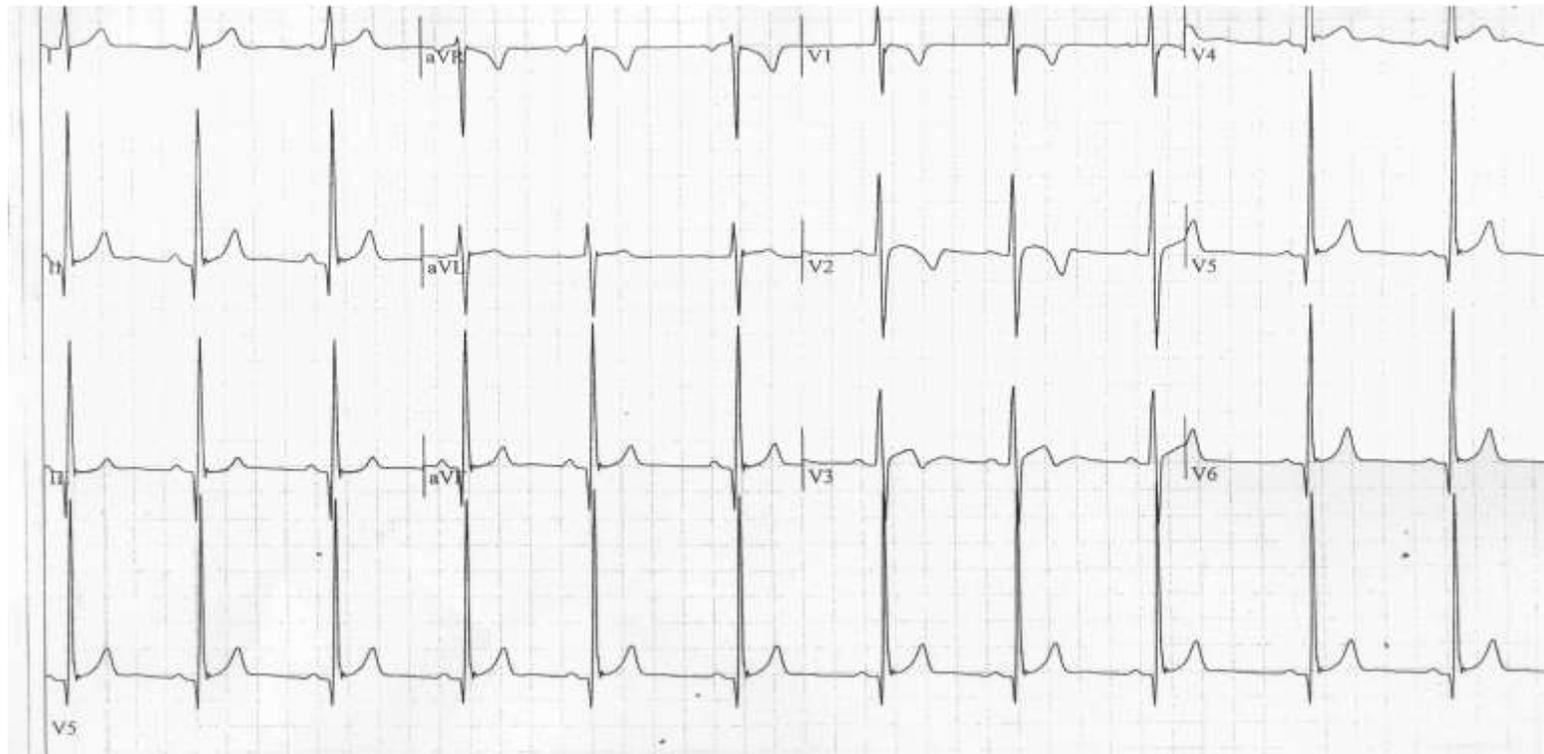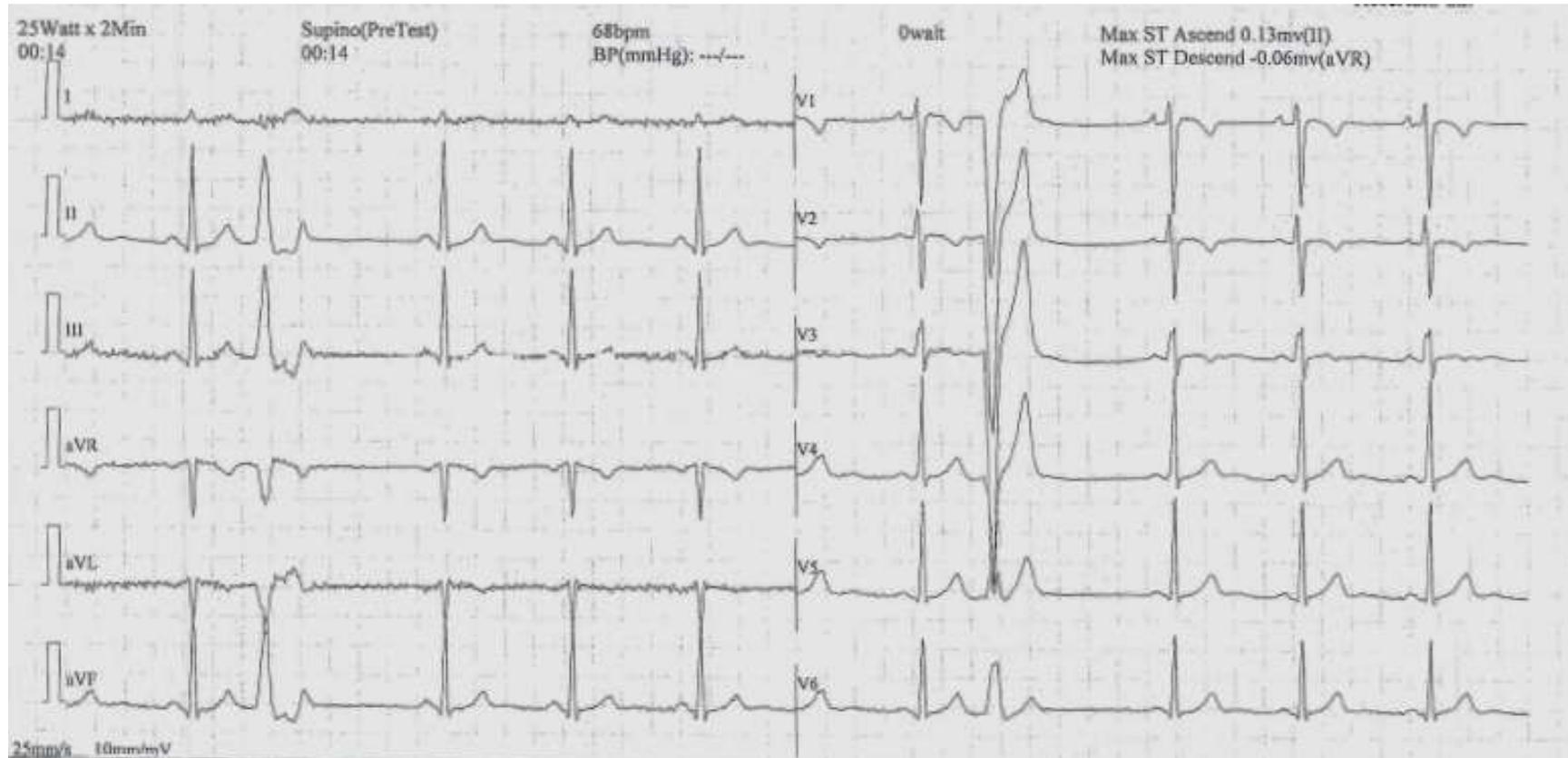| Gruppo 1 Comuni/correlate all'allenamento	Gruppo 2 Non comuni/non correlate all'allenamento	
-Bradicardia sinusale/aritmia sinusale - Ritmo atriale basso - Blocco AV di I grado - BBDx incompleto - Ripolarizzazione precoce - Ipertrofia ventricolare sinistra o destra per soli criteri di voltaggio - Inversione dell'onda T confinata a V1-V4 in età prepuberale o associata a sopraslivellamento ascendente del punto J e del tratto ST (*)	Minori (non comuni nell'atleta, bassa probabilità di patologia se isolati) -Deviazione assiale sinistra - Deviazione assiale destra -Ingrandimento atriale sinistro Ingrandimento atriale destro	Maggiori (non comuni nell'atleta, alta probabilità di patologia) - Inversione dell'onda T ad eccezione di (*) - Sottoslivellamento del tratto ST - Onde Q patologiche - Blocco di branca completo - Ipertrofia ventricolare destra per criteri non di solo voltaggio - Pre-eccitazione ventricolare - QT lungo o corto -Aspetto a tenda (Brugada tipo 1) in V1-V2

Normale o no?

Normale o no?

Normale o no?

Normale o no?

Normale o no?

Normale o no?

Normale o no?

Normale o no?