ECG Screening of Athlete

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COI Disclosure

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Athlete Heart

MEDICAL PROGRESS

THE ATHLETIC HEART SYNDROME

Tim P. Huston, M.D., James C. Puffer, M.D., and Wm. MacMillan Rodney, M.D.

In the process of training, the getting wind, as it is called, is largely a gradual increase in the capability of the heart. . . . The large heart of athletes may be due to the prolonged use of their muscles, but no man becomes a great runner or oarsman who has not naturally a capable if not a large heart.[1]

THE heart of an athlete has certain functional and morphologic adaptations that distinguish it from other hearts. The capacity to perform vigorous physical activity depends on the integrated functioning of many systems. The cardiovascular system plays a pivotal part, since continuous muscular work ultimately depends on transport of oxygen to the muscle being used.

The "athlete's heart" should be viewed as reflecting a normal physiologic response to repetitive exercise.

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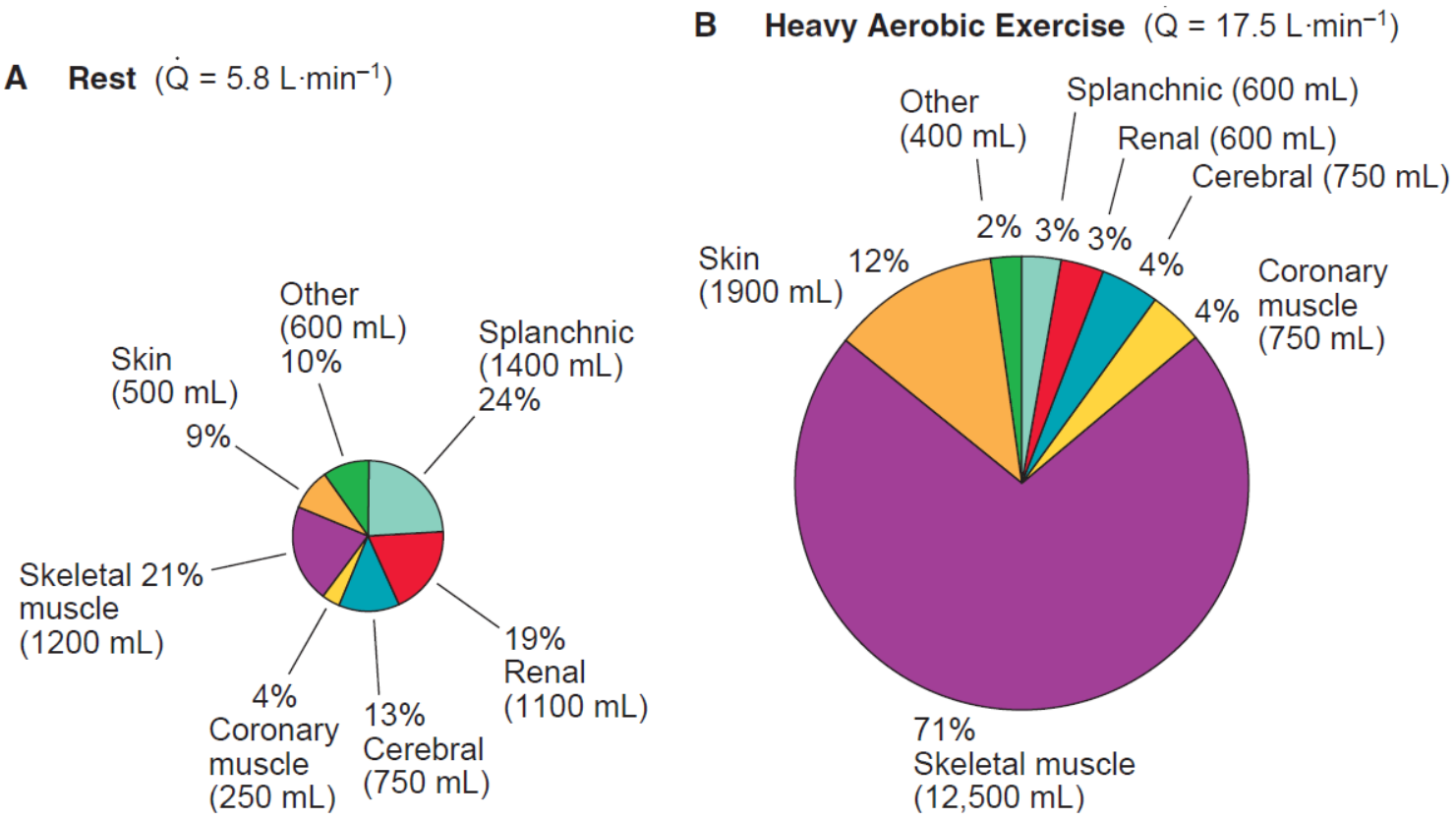
The purpose of this review is to present this constellation of clinical findings.

The Physiologic Component

Physiologically, the heart maintains its ability to function adequately as a pump by altering heart rate and contractility when a sudden demand is placed on it. However, when a long-term demand is imposed on the heart, pump function is maintained by means of cardiac adaptive responses. Chronic demand can be of two basic types: demand related to pressure overload, and demand due to volume overload. When pressure overload is chronic, the heart responds by increasing septal and free-wall thickness to normalize myocardial-wall stress (LaPlace's law). When chronic volume overload occurs, left ventricular end-diastolic diameter increases, with a proportional increase in septal and free-wall thickness to normalize wall stress. The increase in the diameter and in ventricular wall thickness can be considered appropriate compensation for the chronic volume overload placed on the

NEJM 1985

Distribution of Cardiac Output at Rest and during Heavy Aerobic Exercise

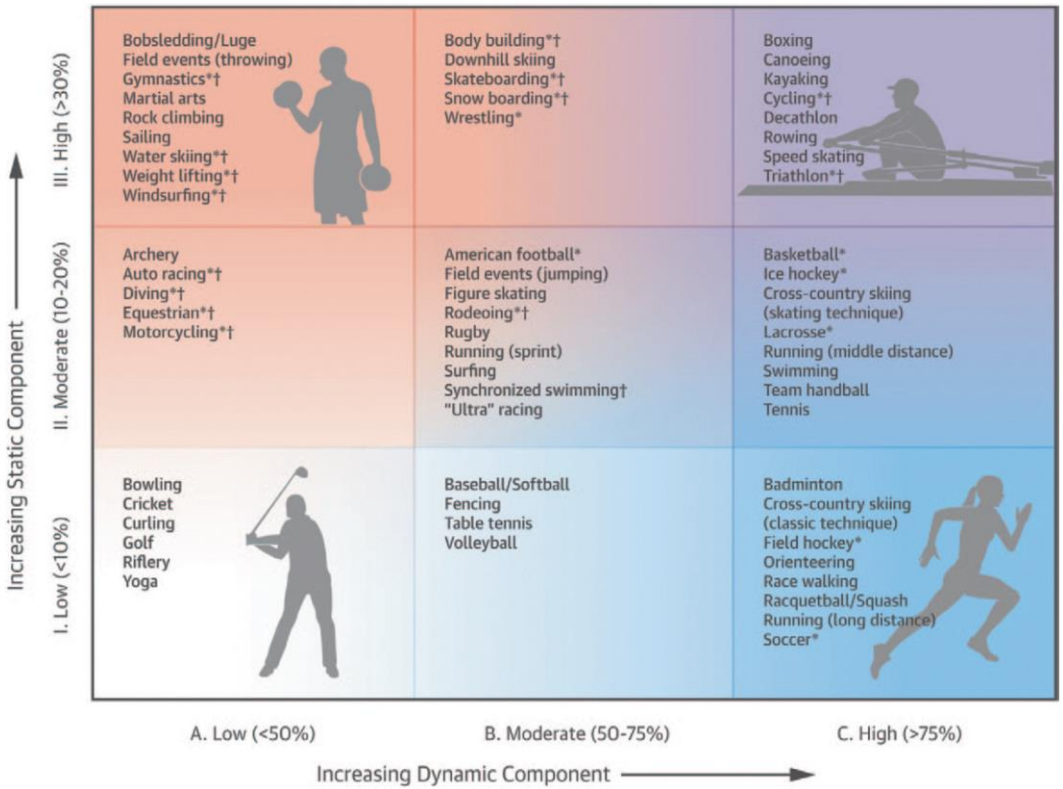


Exercise Physiology. New York, NY: Academic Press (2017)

Factors for remodeling

- Type of exercise
- Duration and strength of exercise
- Gender difference
- Ethnic difference

Classification of sports



- The increasing dynamic component is defined in terms of the estimated percentage of maximal oxygen uptake ($V\dot{O}_{2max}$) achieved and results in an increasing cardiac output.
- The increasing static component is related to the estimated percentage of maximal voluntary contraction reached and results in an increasing blood pressure load.

JACC 2017

Why athletes should be screened?

- ✓ Sudden cardiac death (SCD) is a tragic outcome for athletes and their families.
- ✓ Although, relatively rare, SCD is the leading cause of death for people playing sport.

SCD in athlete

The physical endeavor of sport activity and training poses a 2.4 to 4.5 increased risk of SCA and SCD relative to that in nonathletes and recreational athletes

D. Corrado, et al. Trends in sudden cardiovascular death in young competitive athletes after implementation of a preparticipation screening program JAMA, 2006, 1593-1601
E. Marijon, et al. Sports-related sudden death in the general population. Circulation 2011, 672-68
B.G. Toresdahl, et al.Incidence of sudden cardiac arrest in high school student athletes on school campus. Heart Rhythm, 2014, 1190-1194

Sudden cardiac death

- US data from a single-state registry suggest a sudden death prevalence of 1:200 000 per year, whereas data from the Italian preparticipation screening program suggest a significantly higher rate.
- Hypertrophic cardiomyopathy is the most common cause of sudden cardiac death in the young in the United States.
- male athletes have a 3 to 5 times higher incidence of SCD than female athletes

Cause of SCD in Athlete

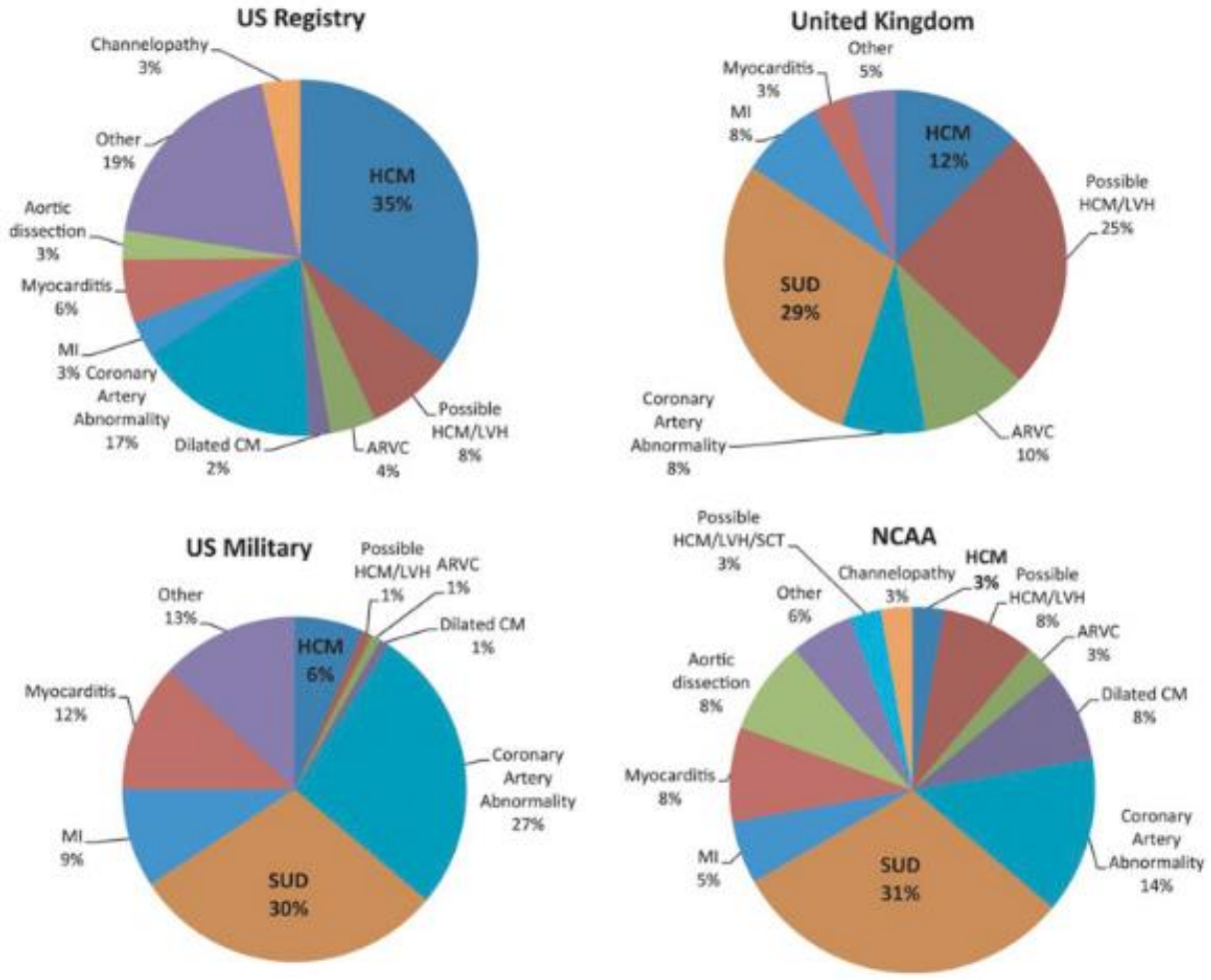
Table 1. Causes of Sudden Death in 387 Young Athletes.*

Cause	No. of Athletes	Percent
Hypertrophic cardiomyopathy	102	26.4
Commotio cordis	77	19.9
Coronary-artery anomalies	53	13.7
Left ventricular hypertrophy of indeterminate causation†	29	7.5
Myocarditis	20	5.2
Ruptured aortic aneurysm (Marfan's syndrome)	12	3.1
Arrhythmogenic right ventricular cardiomyopathy	11	2.8
Tunneled (bridged) coronary artery‡	11	2.8
Aortic-valve stenosis	10	2.6
Atherosclerotic coronary artery disease	10	2.6
Dilated cardiomyopathy	9	2.3
Myxomatous mitral-valve degeneration	9	2.3
Asthma (or other pulmonary condition)	8	2.1
Heat stroke	6	1.6
Drug abuse	4	1.0
Other cardiovascular cause	4	1.0
Long-QT syndrome§	3	0.8
Cardiac sarcoidosis	3	0.8
Trauma involving structural cardiac injury	3	0.8
Ruptured cerebral artery	3	0.8

* Data are from the registry of the Minneapolis Heart Institute Foundation.[6,28]

NEJM 2005

Comparison of Pathogenesis of Sudden Cardiac Deaths in Athletic Populations



K.G. Harmon, et al. Circ Arrhythm Electrophysiol, 7 (2014), pp. 198-204

Sudden cardiac death

- Sudden death has been documented in most types of competitive sports, but may be more common during participation in physically intense sports, such as basketball, soccer, and American-style football.

- Sex and ethnicity appear to contribute to sudden death risk, with male participants and individuals of Afro-Caribbean descent more likely to succumb to sport-related sudden death.

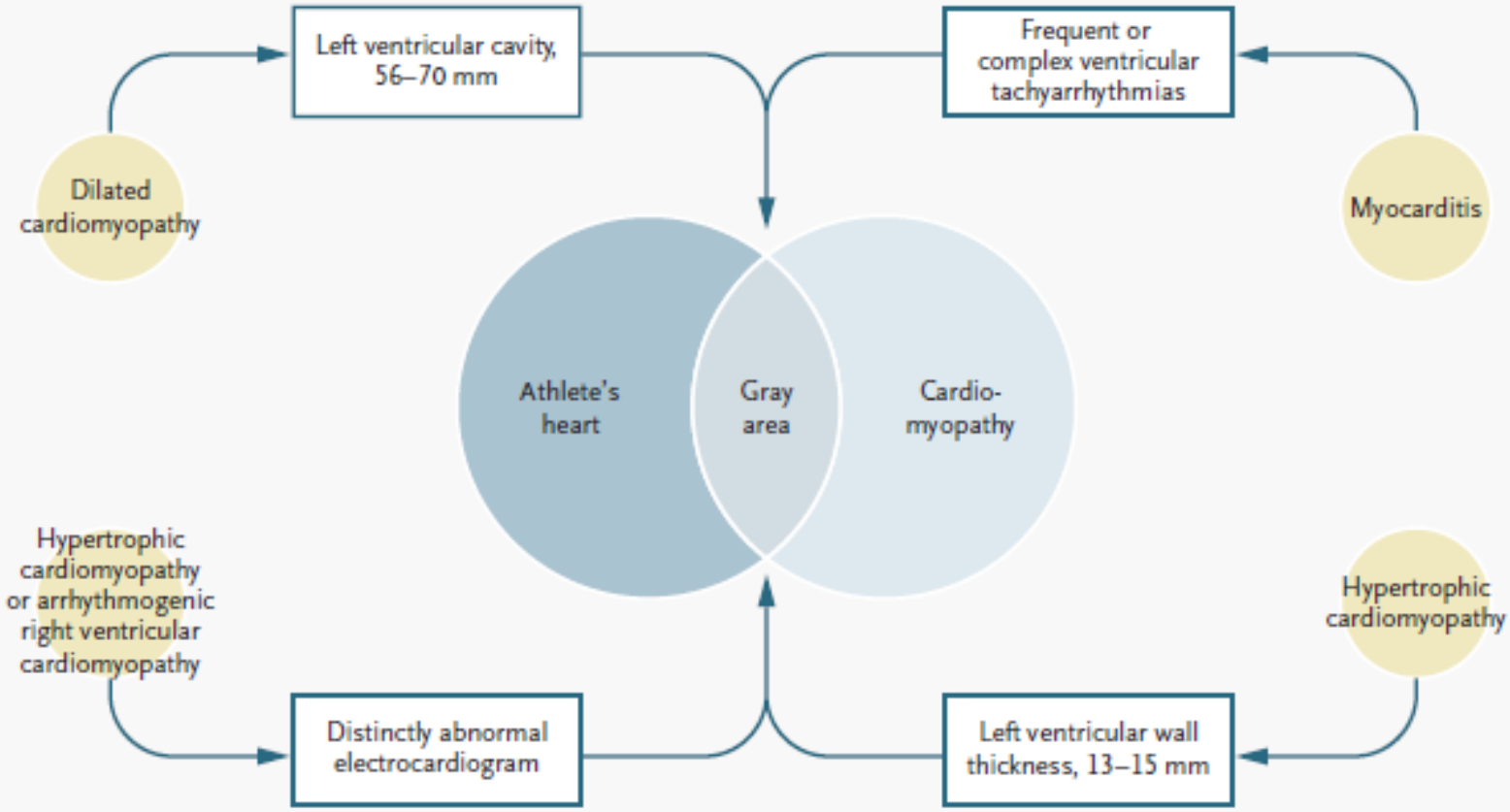


Figure 4. Gray Area of Overlap between Athlete's Heart and Cardiomyopathies, Including Myocarditis, Hypertrophic Cardiomyopathy, and Arrhythmogenic Right Ventricular Cardiomyopathy.

The important diagnostic features compatible with both physiologically based adaptations to athletic training (athlete's heart) and the pathologic conditions are shown.

Preparticipation screening in athlete

Screening of athlete

- The AHA/ACC and the ESC have published consensus committee-based recommendations for preparticipation athlete screening. Both governing bodies recommend a focused medical history and physical examination.

- The ESC recommends the addition of a 12-lead ECG. This addition of a 12-lead ECG to medical history and physical remains an area of intense debate. Observational data from the Italian national experience and recent prospective trial data from the US suggest that ECG may improve the sensitivity of preparticipation cardiovascular screening.

Screening of athlete

The American Heart Association preparticipation screening recommendations

Medical history (personal)

- Exertional chest pain or discomfort.
- Syncope or near-syncope.
- Excessive exertional and otherwise unexplained dyspnea.
- Fatigue association with exercise.
- Prior recognition of a heart murmur.
- Elevated systemic blood pressure.

Family history

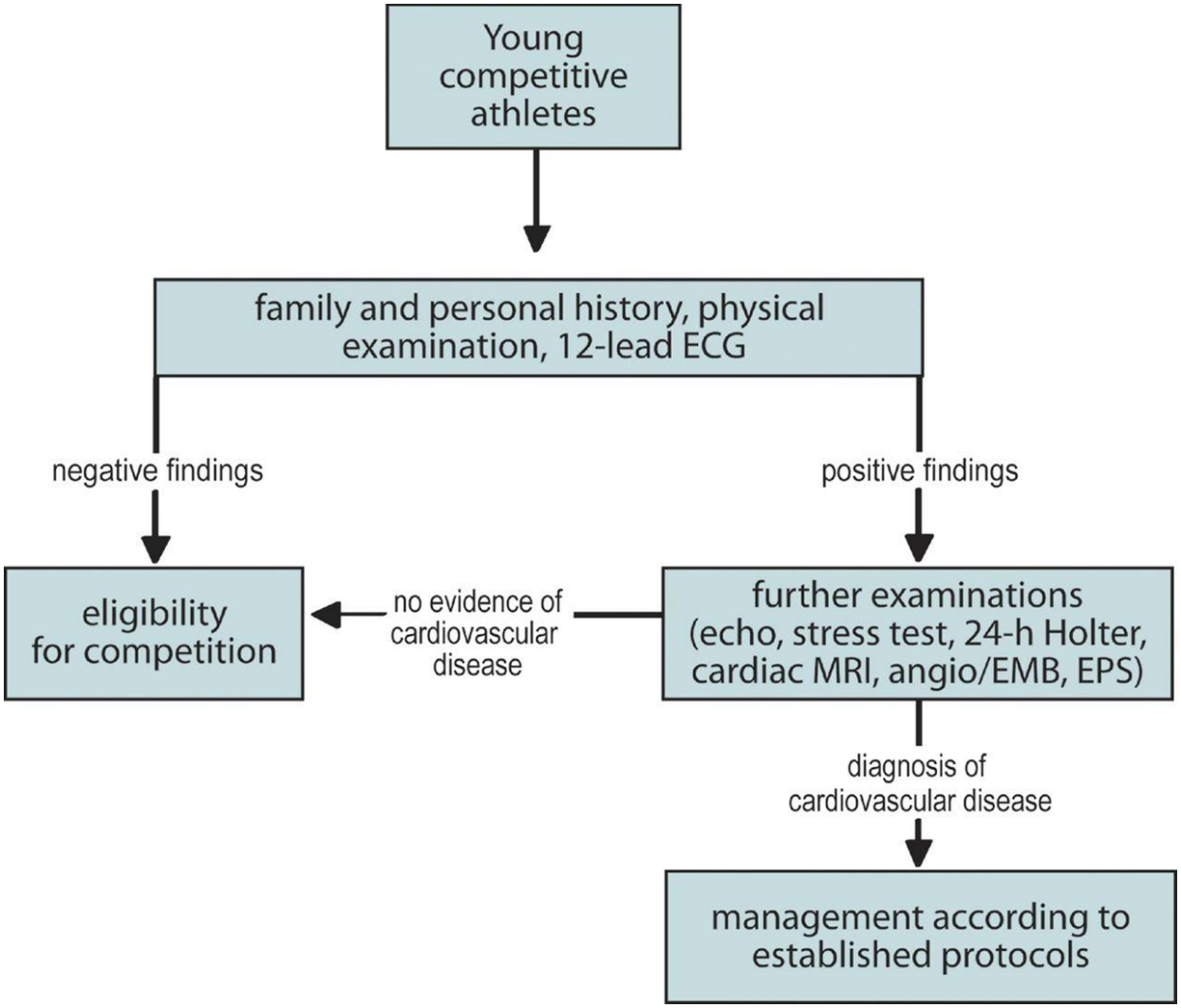
- Premature death (sudden or otherwise) before age 50 years related to heart disease in one or more relatives.
- Disability from heart disease in a close relative <50 years old.
- Specific knowledge of certain cardiac conditions in family members.

Physical examination

- Heart murmur.
- Femoral pulses to exclude aortic coarctation.
- Physical stigmata of Marfan syndrome.
- Brachial artery blood pressure (sitting position).

***Ann Intern Med* 2006; 145:507-511**
***JACC* 2016; 25:29081-2995**

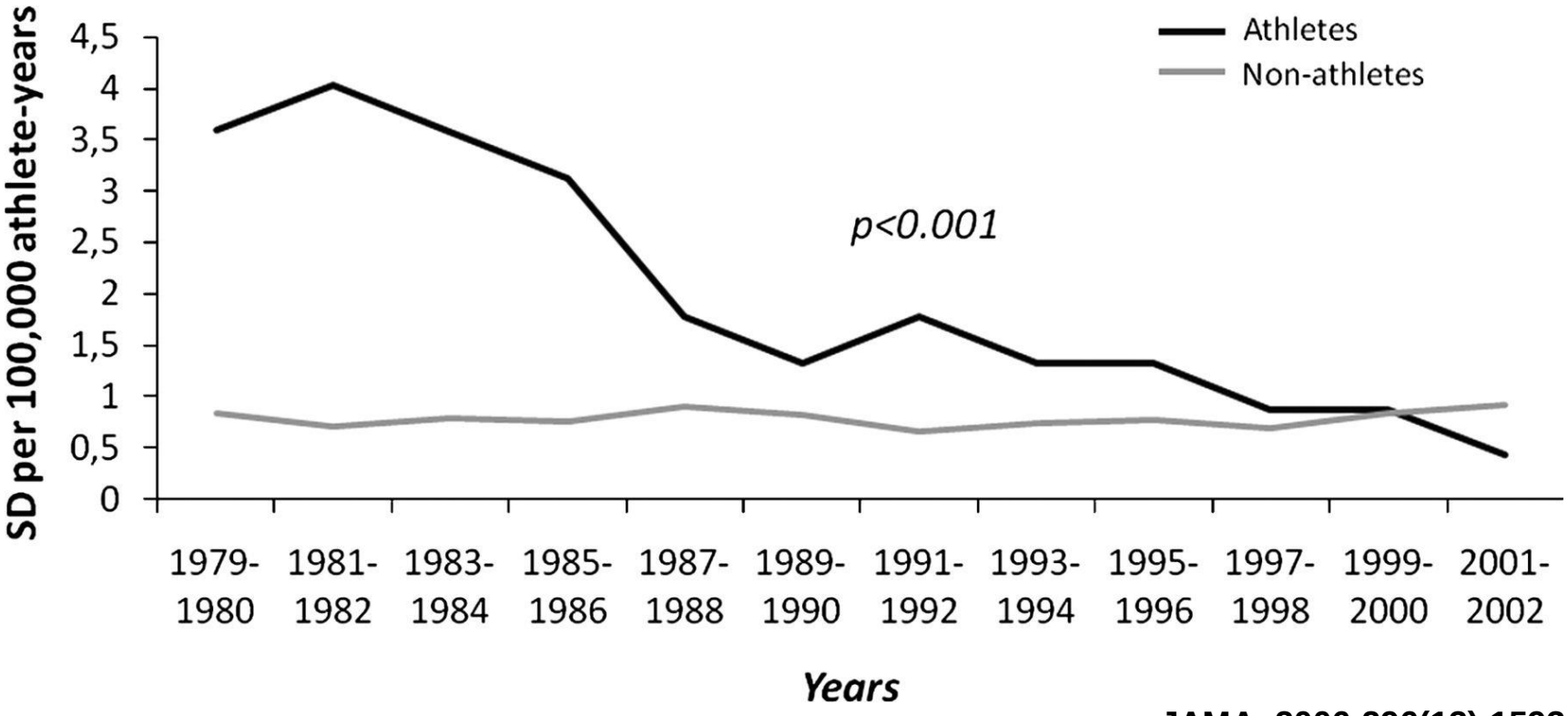
The Italian protocol of preparticipation screening



Thiene G et al. Heart 2013;99:304-306

During the study period, the annual incidence of SCD decreased by 89% in screened athletes (P for trend <.001).

In contrast, the incidence rate of SCD did not demonstrate consistent changes over time in unscreened nonathletes.



JAMA. 2006;296(13):1593-1601.

ECG change in athlete heart

Athlete's heart

Neuroautonomic changes

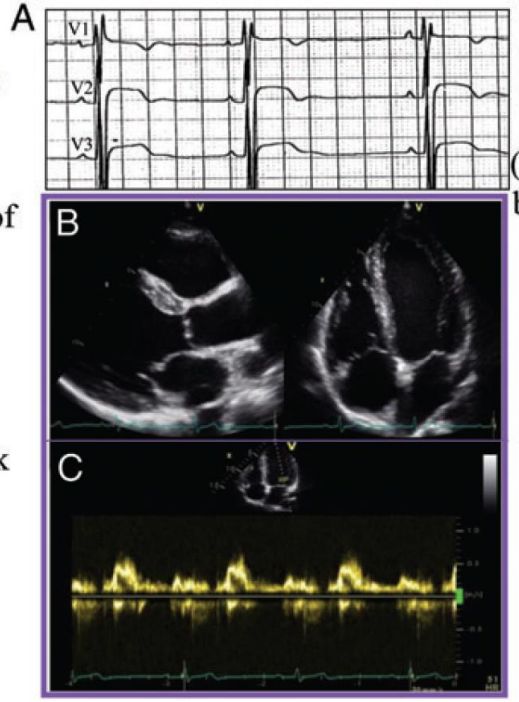
Increased vagal tone and/or withdrawal of sympathetic activity

ECG changes:

Sinus bradycardia

1° and 2° degree AV block

Early repolarization



Structural changes

Increase of ventricular mass (LV and RV) due to increase o both cavity dimension and wal thickness

ECG changes:

Increase of QRS voltages

Incomplete RBBB

Functional changes

Normal diastolic filling pattern

Preserved systolic function

Increased stroke volume

JACC 2013

ECG screening

- ✓ The European Association of Preventive Cardiology (EAPC) recommends screening (including a resting ECG) asymptomatic middle-age/senior individuals engaging in high-intensity sport.

- ✓ In Italy and Israel, ECG screening of all young athletes (of any level) is mandated, whereas in most other countries ECG screening of athletes is restricted to those at the elite level.

Heart rhythm 2019

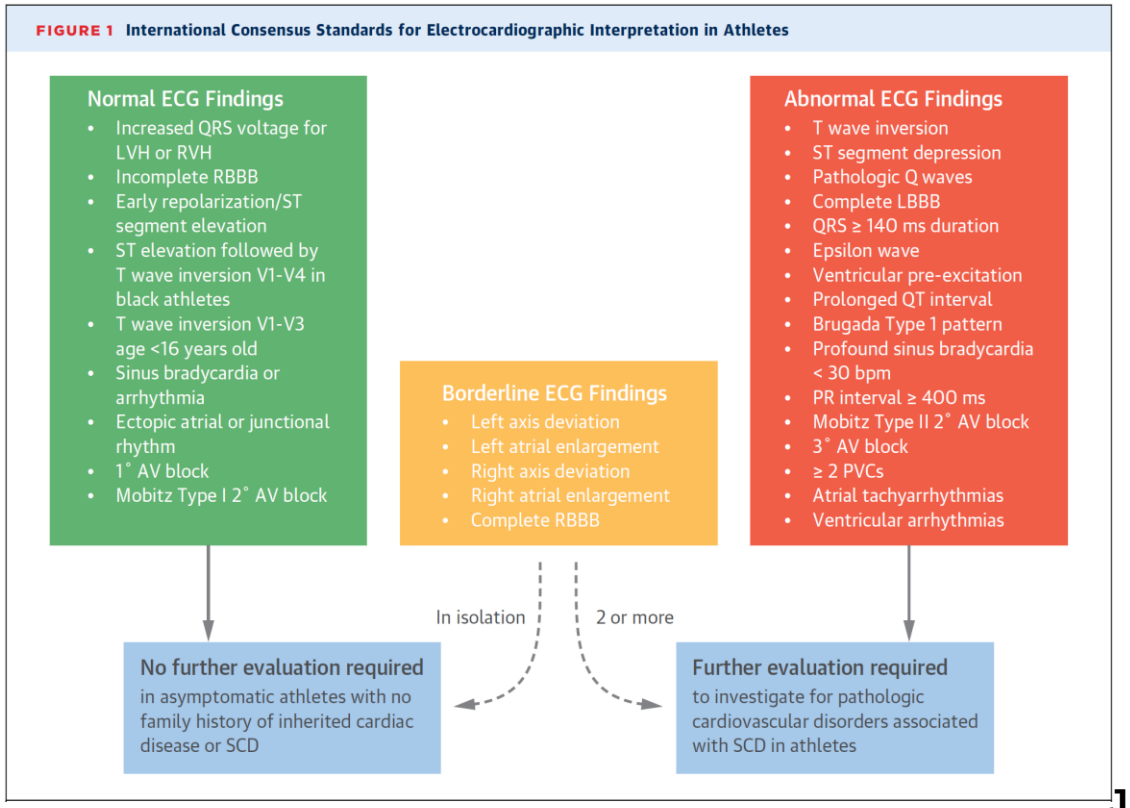
Screening of athlete

Classification of abnormalities of the athlete's electrocardiogram

Group 1: common and training-related ECG changes	Group 2: uncommon and training-unrelated ECG changes
Sinus bradycardia	T-wave inversion
First-degree AV block	ST-segment depression
Incomplete RBBB	Pathological Q-waves
Early repolarization	Left atrial enlargement
Isolated QRS voltage criteria for left ventricular hypertrophy	Left-axis deviation/left anterior hemiblock
	Right-axis deviation/left posterior hemiblock
	Right ventricular hypertrophy
	Ventricular pre-excitation
	Complete LBBB or RBBB
	Long- or short-QT interval
	Brugada-like early repolarization

EHJ 2010

International Recommendations for Electrocardiographic Interpretation in Athletes



JACC. 2017;69:1057-75.

The feature of cardiac electrical and structural remodeling in elite soccer players

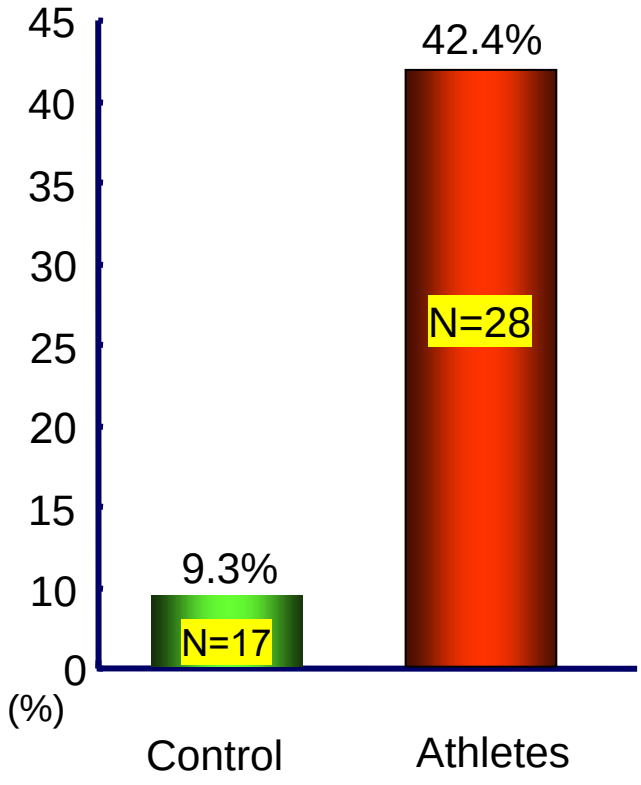
	Controls (n=182)	Athletes (n=66)	P-value
Age (years)	23.8 ± 2.4	23.1 ± 2.7	0.274
Sex (male, %)	72 (39.6%)	24 (36.4%)	0.684
Weight (Kg)	69.6 ± 9.9	78.7 ± 7.7	<0.001
Height (cm)	173.8 ± 5.5	183.3 ± 6.1	<0.001
BMI (kg/m^2)	23.0 ± 2.7	23.3 ± 1.2	0.526
BSA (m^2)	1.8 ± 0.1	2.0 ± 0.1	<0.001
Systolic BP (mm Hg)	119.2 ± 10.0	120.7 ± 8.3	0.503
Diastolic BP (mm Hg)	73.1 ± 8.1	63.9 ± 5.1	<0.001
Heart rate (bpm)	67.5 ± 8.8	55.2 ± 6.1	<0.001

Elite Athlete: national soccer teams and reserve
Controls: healthy person

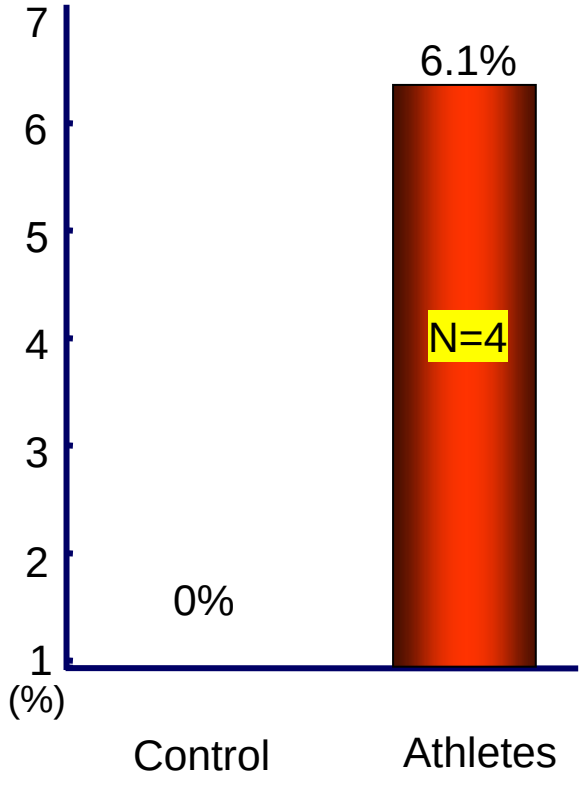
Europace 2015.

Positive ECGs by different criteria

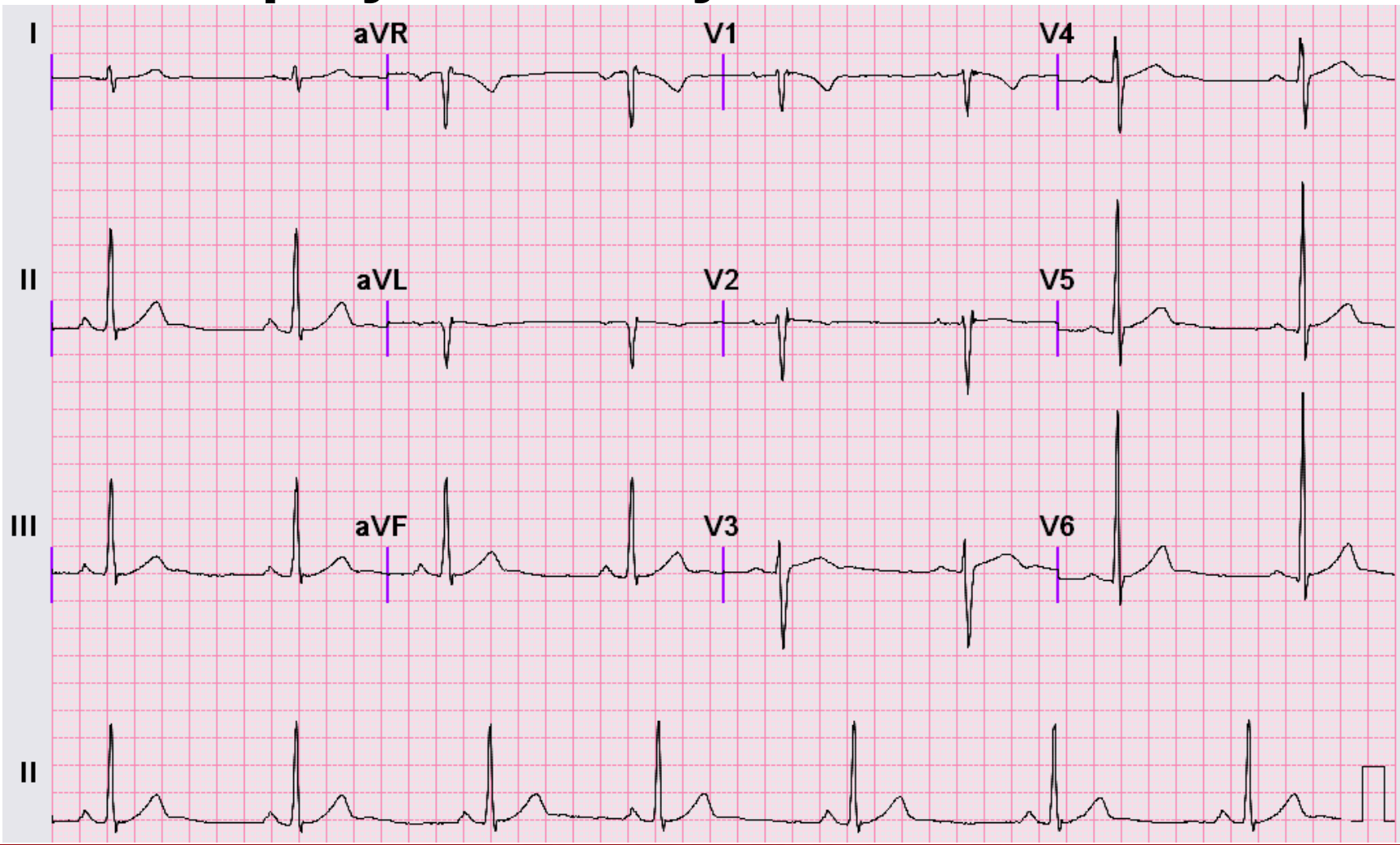
ESC guideline (2010)



Seattle criteria(2013)



M 27
soccer player for 14 yrs



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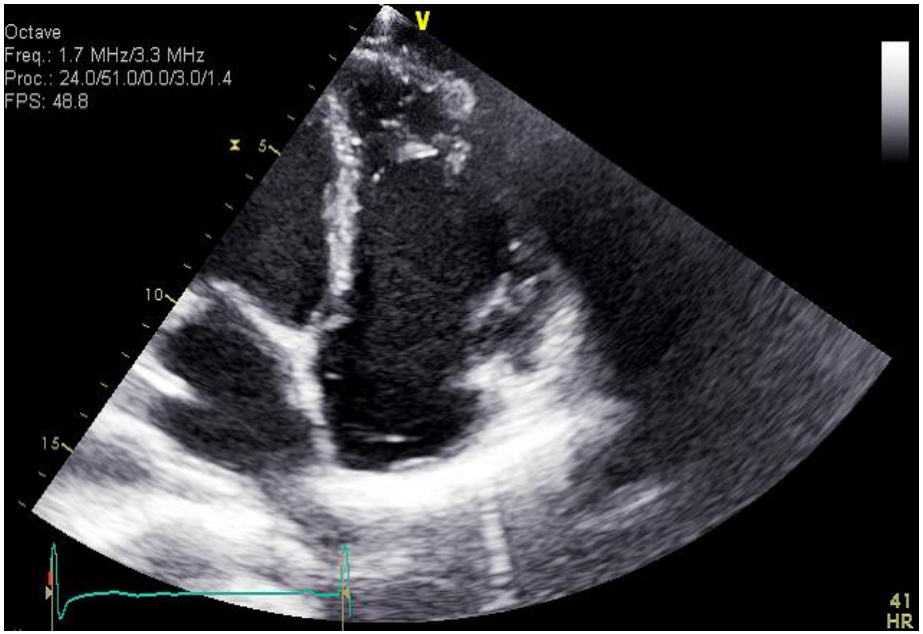


Athlete

Control

Debate for ECG screening

Arguments in favour of ECG

- A 12 lead basal ECG is a non-expensive, largely available test for a mass screening of athletes.
- The ECG screening modality has proven more sensitive than the history and physical examination protocol.[117]
- ECG is abnormal in >80% of individuals with cardiomyopathies (*hypertrophic cardiomyopathy*[31,32] *and arrhythmogenic right ventricular cardiomyopathy*[36]), myocarditis, pre-excitation syndromes, and ion channel disorders which are the leading causes of cardiac arrest in young athletes. Together these conditions account for up to the two-thirds of SCD in young competitive athletes.
- Modern diagnostic criteria offer the potential to standardise and simplify the interpretation of ECGs and improve diagnostic accuracy.[121]
- There has been a notable decline (~90%) of SCD among young competitive athletes after implementation of the nationwide Italian ECG screening programme over 25 years of observation.[3]

Arguments against ECG

- The evidence for a survival benefit of ECG screening is limited to a single observational study.
- Highly trained athletes may develop ECG anomalies mimicking cardiomyopathies causing SCD.[33,34]
- Misinterpretation of 12 lead ECG is not uncommon particularly in non-specialized physicians,[126] leading to an expensive diagnostic work-up or unnecessarily disqualifying athletes because of normal ECG variants; conversely, potentially lethal heart disease may be misinterpreted as normal variants of the athlete's ECG.
- Some cardiovascular disorders at risk of sudden death are not associated with ECG changes (*Marfan syndrome, premature coronary heart disease, congenital coronary anomaly*[53]).
- False-positive results yield a high number of work-up tests that accounts its high cost and jeopardizes cost effectiveness of ECG screening programmes.[163-168]
- Abnormal ECG findings lead to disqualification of up to 2% of athletes from competitive sports.[3]

ESC 2017

Cost-effectiveness of ECG screening

- in California, high school and college athletes aged 14–22 years, a scr eening ECG was found to save 2.06 life-years per 1000 athletes scree ned at an incremental cost of US $89 per athlete, with an overall cost-effectiveness ratio of US $42 900 per life-year saved

- Screening ECG cannot pick up all potential causes of sudden death among athlete, particularly coronary disease, while other cause of cardiac arrest, such as myocarditis (or commotio cordis) will be unaffected by screening

The NEW ENGLAND JOURNAL of MEDICINE

CLINICAL DECISIONS

INTERACTIVE AT NEJM.ORG

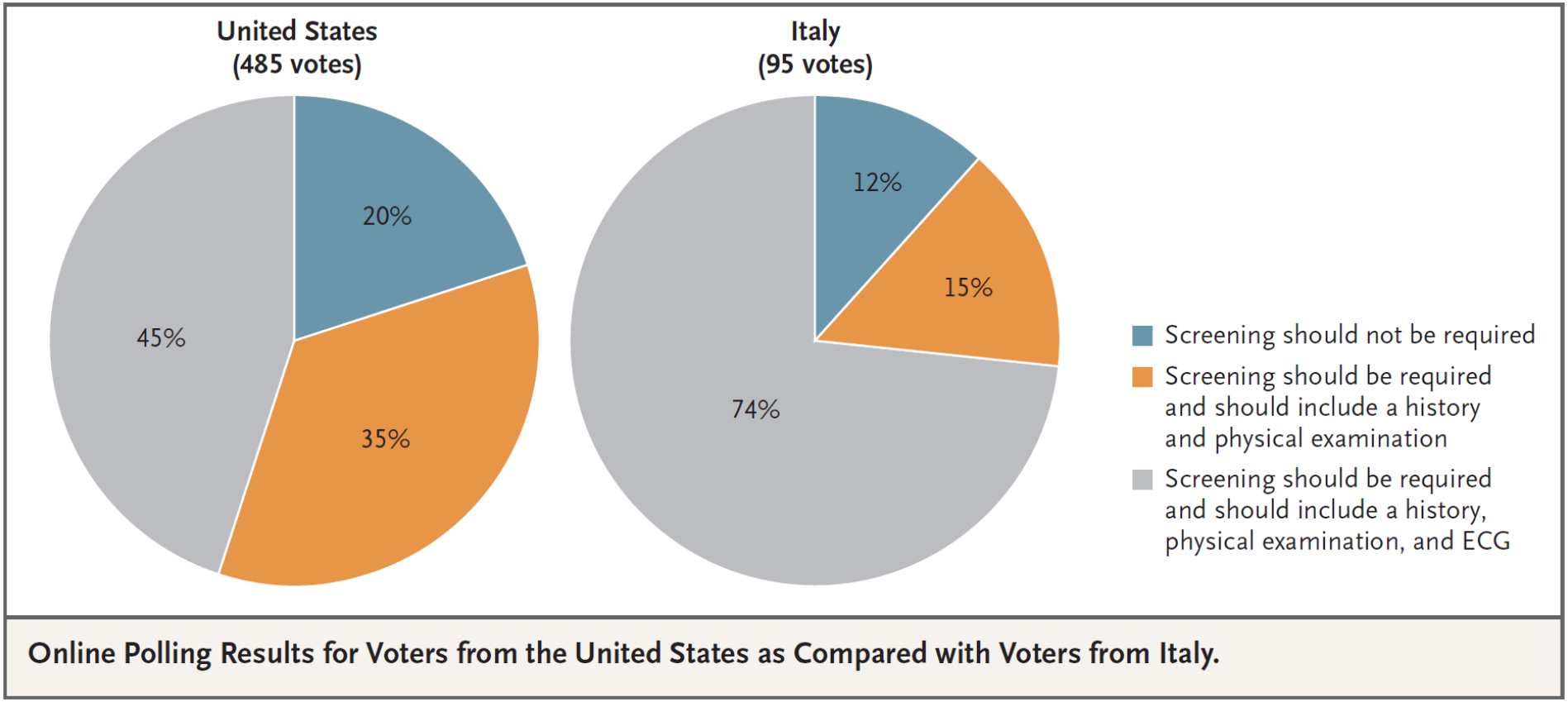
Cardiac Screening before Participation in Sports — Polling Results

James A. Colbert, M.D.

NEJM 2014;10;370

Online polling for Cardiac Screening in Sports

In response to our online poll, our website received 1266 votes from 86 countries.



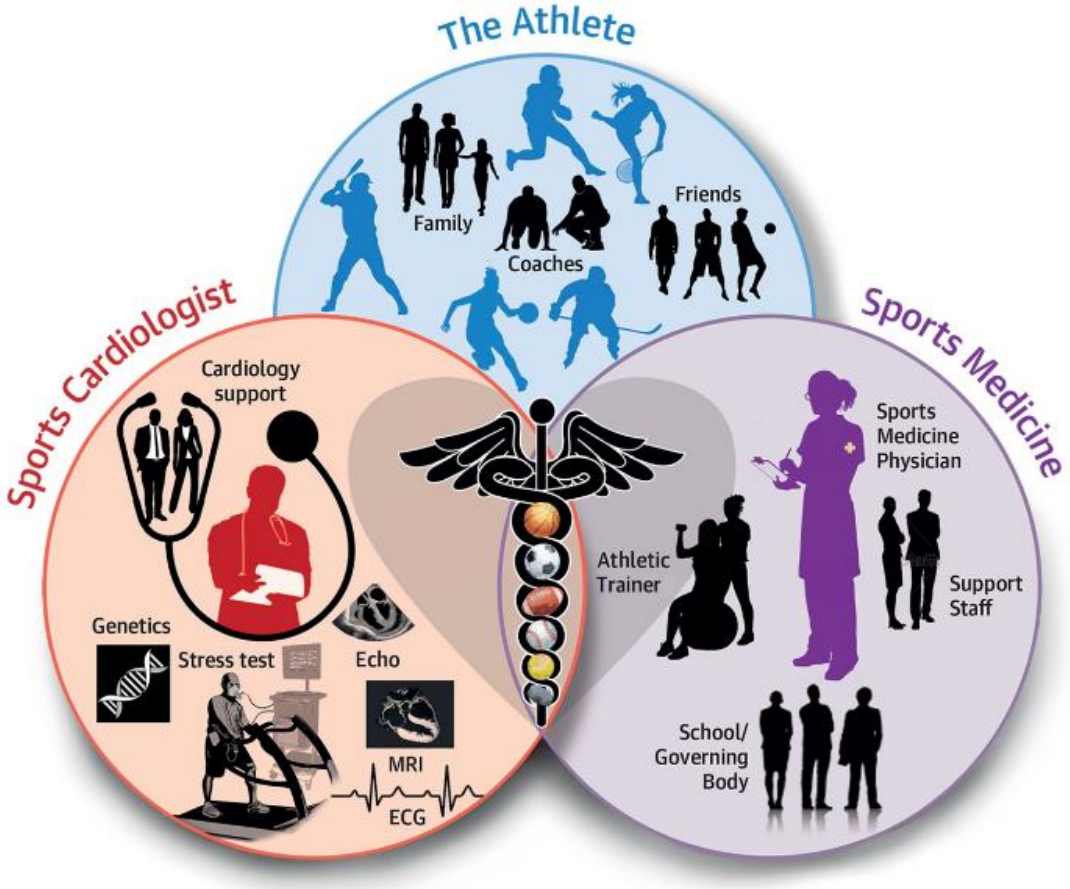
Online Polling Results for Voters from the United States as Compared with Voters from Italy.

Recommendation of the screening protocols currently implemented by international sporting organizations.

Sporting Federation	Mandatory or recommended	Screening protocol	Primary screening methodology			
			Physical examination	Personal symptom and FH	12-lead ECG	Echocardiography
International Olympic Committee	Recommend	IOC	✓	✓	✓	
International Paralympic Committee	Recommend	IOC	✓	✓	✓	
Fédération Internationale de Football Association	Mandate	Self-imposed	✓	✓	✓	✓
Union of European Football Associations	Mandate	Self-imposed	✓	✓	✓	✓
Union Cycliste Internationale	Mandate	Self-imposed	✓	✓	✓	✓
Fédératoin Internationale de Motocyclisme	Mandate	Self-imposed	✓	✓	✓	✓
Fédération Internationale de l'Automobile	Mandate	Self-imposed	✓	✓	✓	✓
International Association of Athletic Federations	Recommend	IOC	✓	✓	✓	
National Basketball Association (USA)	Recommend	AHA	✓	✓	✓	
National Football League (USA)	Recommend	AHA	✓	✓		
Major League Baseball (USA)	Recommend	AHA	✓	✓		
National Hockey League (USA)	Recommend	AHA	✓	✓		
World Rugby	Recommend	Self-imposed	✓	✓	✓	
Fédération Internationale de Natation	Recommend	Self-imposed	✓	✓	✓	
World Boxing Federation	Recommend	Self-imposed	✓	✓	✓	
International Handball Federation	Recommend	IOC	✓	✓	✓	
International Triathlon Union	Recommend	IOC	✓	✓	✓	
Fédération Internationale de Ski	Recommend	IOC	✓	✓	✓	
Fédération International des Sociétés d'Aviron	Mandate	IOC	✓	✓	✓	

ESC 2017

Team-Based Approach to the Cardiovascular Care of Athletes



Emery, M.S. et al. J Am Coll Cardiol HF. 2018;6(1):30-40.

Conclusion

- Cardiovascular assessment is a vital tool in identifying athletes at risk of sudden cardiac death to mitigate their risk through surveillance, intervention, or participation restriction.
- The decision whether a player is fit to play or not requires a robust risk assessment followed by input from a multidisciplinary team that includes both the team physician and cardiologist.
- In several countries, there is increasing need to setting some guideline for appropriate participation and disqualification including ECG screening.

Thank you for your attention

"He who saves a single life saves the whole world."

—Talmud Sanhedrin 4:5