Cardiovascular screening in young athletes

Controversies and feasibility

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Summary

Sport plays an important role among young people because of its positive physical, psychological and social impact. Nevertheless, for a small minority of subjects affected by cardiovascular abnormalities, sport can be harmful and lead to sudden cardiac death. Although not accepted by all, solid data indicate that a cardiovascular screening with electrocardiogram (ECG) can prevent a substantial part of these tragic events. Based on the Italian experience, the European Society of Cardiology and major sports associations recommend such a screening programme. There are however important controversies about this issue, particularly about the role of ECG in the screening programme. In fact, ECG has been considered to have inherent limitations with a relative amount of false positive results requiring subsequent examinations, which generate increased costs for a programme that should be implemented on a large scale. It is therefore essential that criteria used for the ECG interpretation provide the optimal balance between sensitivity and specificity. With increasing knowledge about the ECG of athletes, recommendations for the interpretation of ECG have been edited. Based among others on our recent experience in a large prospective series, it seems that with specific clinical experience and applying modern and rigorous criteria for ECG interpretation, the screening of young athletes can be realised at a relatively low cost potentially allowing the implementation of this policy on a large scale.

Key words: cardiovascular screening; athlete; sudden cardiac death; electrocardiogram

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Introduction

Regular participation in sports is highly encouraged because it improves fitness, reduces cardiovascular morbidity and mortality, exerts a positive psychological influence and plays an important social role especially for young people. However, intense physical effort can be harmful in subjects affected by cardiovascular abnormalities, and sudden cardiac death (SCD) during sports activities is sometimes the first and definitive manifestation of an underlying silent cardiovascular disease [1]. In fact, in the current era of mediatisation, the cardiac arrest of a professional sportsman, who represents the essence of physical performance, has a profound psychological impact in the community and regularly raises the question about the possibility to prevent such a dramatic event. In this context the debate about the cardiovascular screening of young athletes represents a very controversial issue. The aim of this paper is to review the rationale of cardiovascular screening in young athletes, to discuss some controversies and some practical problems inherent to its actuation and to suggest an approach based on the available literature and on our experience derived from a study recently completed at our centre involving 1,070 young athletes.

Sudden cardiac death in athletes

The incidence of SCD among young athletes (up to 35 years old) is very low at 1–3/100,000 per year [2–4]. The majority of these tragic events occur during or immediately after strenuous physical effort [1, 5]. The relative risk among young athletes versus non-athletes is about 2.8 [1], emphasising the triggering role of the physical effort. SCD is more frequent in males than in females [1], probably because males engage more in sports, particularly in strenuous disciplines, and they more often harbour cardiac diseases. A variety of cardiovascular diseases have been reported to cause SCD in young athletes [6]. The most common cause world-

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wide is hypertrophic cardiomyopathy (HCM), with more than one-third of cases; in Italy arrhythmogenic right ventricular cardiomyopathy (ARVC) is reported to be the main condition causing about one-fourth of cases [1]. The second most frequent cause is congenital coronary artery anomalies, particularly those characterised by wrong aortic sinus origin with about one-sixth of cases. Less common causes include premature atherosclerotic coronary artery disease, myocarditis, channelopathies (particularly long QT syndrome), cardiac conduction diseases, valve diseases, other cardiomyopathies, aortic rupture (Marfan syndrome), and other less frequent causes. Actually, only a small proportion of young subjects are at risk because the abovementioned cardiac diseases have an estimated prevalence of 0.2%–0.6% in the young population [2, 6–9].

Rationale for screening athletes and the Italian experience

Medical evaluation before competition offers the potential to detect still asymptomatic athletes with life-threatening cardiovascular diseases. The experience in the domain of cardiovascular screening in athletes derives largely from the Italian practice which is unique. After a number of sudden deaths of athletes on the field in the seventies, in 1982, the Italian government made a yearly medical evaluation mandatory by law for every subject participating in official sports competitions, independent of age and level of competition [10]. Dedicated sports medical centres with specialised sports physicians were created. The main focus of this medical evaluation is on the cardiovascular examination consisting of history, physical examination, resting ECG and a limited exercise stress test. Further examinations are made in case of positive findings. No participation in official sports competitions is allowed without medical clearance. The costs of this prevention programme are entirely assumed by the National Health System until 18 years of age. According to the experience of the Centre for Sports Medicine in Padua, Italy, from 1982 to 2004 a total of 42,386 athletes were examined, 9% were referred for further examinations and 2% were finally banned from competition because of cardiovascular causes [2]. Applying this screening programme for 25 years, in the Veneto region of Italy a continuous reduction of SCD in young athletes aged 12 to 35 years could be observed, from an incidence of 3.6/100,000/year in the prescreening years (1979–1982) to 0.4/100,000/year in 2003–2004, representing an impressive reduction of almost 90%. Most of the reduced incidence of SCD was attributable to the decrease of deaths due to cardiomyopathies, namely HCM and ARVC. An increasing number of athletes affected by these diseases were identified during screening and disqualified from competitive sports activities. No deaths occurred during long-term follow-up among athletes with HCM who were prevented from taking part to competitive sports. By comparison, the incidence of SCD in the unscreened non-athletic population of the same age remained stable over that time at about 0.8/100,000/year [2].

Controversies about screening

The positive results of the Italian screening programme were not confirmed in Israel, where a similar screening strategy for athletes participating in competitive sports is mandatory by law since 1997. The average yearly incidence of SCD during the decade before and after the implementation of the programme was very similar: 2.54/100,000 and 2.66/100,000, respectively [4]. One reason evoked by the authors of this study for the high efficacy of the Italian screening programme could be the incidental fluctuation of the SCD rate with abnormally high values during the initial period of the study artificially augmenting the positive results of the screening. However, compared to the Italian data, methodological limitations partly hamper the authors' conclusions.

In Minnesota (USA), where screening is not mandatory, the incidence of SCD in athletes was relatively constant over 23 years and similar to the rate observed in the Italian study after 25 years of screening and restriction to sports [3]. Criticism of this study arose due to methodological problems in the collection of SCD cases of athletes. In addition, the study population was not completely comparable to the Italian one (younger age and higher prevalence of female subjects who have a lower incidence of SCD).

The usefulness and modalities of cardiac screening in athletes is therefore the subject of ongoing animated controversies [11, 12].

Nevertheless, based on the robust and longstanding Italian experience, in 2005 the European Society of Cardiology (ESC) published recommendations about the cardiovascular screening in young athletes [13]. Athletes aged from 12 to 14 years should undergo regular exams (every one to two years) including history, physical examination and ECG. If there is no evidence of cardiovascular diseases, the athlete is eligible for competition. In case of positive findings, further examinations will be undertaken to exclude cardiac abnormalities according to established clinical practice. This approach has been endorsed by major sports associations as the International Olympic Committee and the Fédération Internationale de Football Association [14, 15].

In the Unites States, the American Heart Association (AHA) also recommends screening of young athletes, albeit limited to history and physical examination [6]. Although American authors have acknowledged the possible benefits of the ESC strategy, many have expressed concerns over its implementation in the United States; in particular they point the finger to the mandatory character of testing, cost-effectiveness, availability of qualified physicians and, especially, the presumed low specificity of ECG, resulting in additional examinations and high costs for a programme that should be offered to a very large population to prevent a relatively low number of deaths. In this respect it is appropriate to remember that a cardiac screening programme of young competitive athletes up to 35 years, intended to be implemented at large scale, would include an estimated 5% to 10% of the entire population [13], a huge number of subjects. The screening, by definition, should be able to identify most affected individuals (high sensitivity), have a low false negative rate (high specificity) and be relatively cheap to be implemented on a large scale.

In Switzerland screening is not mandatory and there are only official recommendations for top-level athletes of the Swiss Society of Sports Medicine, similar to the ESC 2005 criteria [16]. Some sports federations require for professional athletes a medical evaluation with cardiovascular screening in order to obtain the licence of the club.

Cardiovascular screening: practical implementation

Below we allude to different pragmatic aspects of the cardiovascular screening examination on the basis of the 2005 ESC recommendations [13], with particular emphasis to the ECG interpretation.

History

The family history should focus on potentially inherited cardiac conditions, the personal history on classical cardiovascular symptoms (table 1). Among athletes victims of SCD, 10%–18% had a family history of premature cardiac diseases and 18%–50% had previous cardiovascular symptoms [2, 5, 17, 18].

In our experience, it is not rare for young athletes to report symptoms of potential cardiovascular relevance like chest pain, vague palpitations, shortness of breath or dizziness. A good clinical experience aids in recognising complaints of cardiac origin, thus avoiding unnecessary subsequent examinations. On the other hand, especially elite athletes, sometimes conceal symptoms, or mitigate them for fear of discovering diseases that could potentially hamper their sport's career.

In a different series [7–9, 19–21], up to 5.4% of young athletes had pathological elements in their family or personal history requiring further examinations.

Physical examination

The physical examination is aimed at identifying hypertension, valvular heart diseases, coarctation of the aorta and the Marfan syndrome (table 2). During cardiac auscultation of a young subject, care should be taken to distinguish an innocent ejection murmur, a physiologic splitting of the first heart sound, a third heart sound, or a respiratory splitting of the second heart sound from an organic murmur or a pathologic heart sound. Extensive clinical experience is invaluable in order to avoid a multitude of unnecessary echocardiographic examinations to "rule out" organic anomalies.

Because of abnormal elements in the physical examination, up to 3.5% of young athletes in different studies [7–9, 19–21] required further cardiac examinations.

Electrocardiogram

Particular emphasis is given to the role of ECG in the screening strategy. In fact, ECG is pathological in about 80% of subjects with HCM or ARVC, the main causes of SCD in the young sport population, as well as in other cardiomyopathies [11]. Moreover ECG allows the diagnosis of a Wolff-Parkinson-White pattern and

Table 1
Family history and personal history criteria suggesting a potentially inherited cardiac condition respectively an underlying cardiovascular disease (modified from [2, 6]).

Family history	Premature sudden cardiac death in ≥1 relative before age 50 years
	Family history of coronary artery disease <50 years, cardiomyopathies, channelopathies, important arrhythmias, Marfan or other serious cardiovascular diseases <50 years
Personal history	Syncope or near-syncope of undetermined origin
	Exertional chest pain or disconfort
	Abnormal shortness of breath or fatigue during exercise
	Palpitations

Table 2
Criteria for abnormal cardiovascular physical examination in a young athlete (modified from [2, 6]).

Features suggestive of Marfan syndrome
Diminished and delayed femoral pulses
Brachial blood pressure (sitting bilateral) ≥140/90 (≥135/85 mm Hg if ≤17 years) on >1 reading
Irregular heart rhythm
Mid- or end-systolic clics
Abnormal second heart sound (single or widely split and fixed with respiration)
Heart murmur (supine, standing and with Valsalva): systolic ≥ $^{2}/_{6}$ and any diastolic

can detect channelopathies such as long and short QT syndrome, Brugada syndrome and Lenègre syndrome. On the other hand, the possibility to detect congenital coronary anomalies (an important cause of SCD in the young) or premature coronary atherosclerosis, is limited. Other rare electrical diseases such as catecholaminergic polymorphic ventricular tachycardia cannot be diagnosed through a resting ECG. Channelopathies have ECG patterns with significant overlap with normal subjects and their detection can be improved by performing serial ECG but diagnosing all individuals harbouring these diseases is virtually impossible [22]. Nevertheless, adding ECG to history and physical examination allows to identify about two-thirds of athletes potentially at risk [11] and obviously adds considerably to the efficacy of the screening strategy. Despite this, there is a continuing debate between American and European experts about the role of ECG in cardiac screening of athletes and the AHA, as stated previously, doesn't recommend ECG as part of screening [6].

The interpretation of ECG of a young athlete is a difficult task. In a recently published study the accuracy of pediatric cardiologists in distinguishing conditions causing SCD from normal ECG of young athletes was only 69% [23]. Errors in differentiating physiological and pathological abnormalities may have serious consequences. Athletes may undergo unnecessary expensive diagnostic work-up creating anxiety, not only for the athletes themselves but also for their families and doctors. This can lead to incorrect diagnoses and sometimes to the prohibition from sport participation with all the negative consequences on psychological, physical and sometimes financial aspects. Alternatively, misinterpreting ECG signs of potentially lethal diseases as normal variants may have tragic consequences. Litigation based on ECG interpretation of an athlete is a possible threat.

In a landmark study published in 2000, Pelliccia et al. reported that 40% of 1,005 ECGs of highly trained adult athletes were considered to have findings possibly associated with cardiovascular diseases and 14% were distinctly abnormal [24]. Similar findings were reported by Sharma et al. on 1,000 ECGs of elite adolescent athletes [25]. Some authors have therefore considered that physiologic ECG changes overlap significantly with ECG abnormalities seen in cardiovascular diseases and, because of presumed high level of false positive results, this has led to the perception that ECG is a non-specific tool for the cardiac evaluation of athletes [6].

ECG criteria used in the general non-athletic population cannot be utilised in many aspects for the interpretation of an athlete's ECG. In addition, there are historical inconsistencies in the definition of some ECG abnormalities.

A first step toward the correct interpretation of an athlete's ECG was the ESC 2005 document in which criteria for positive ECG were published [13]. Besides standard ECG abnormalities, conservative voltage amplitude criteria for left ventricular hypertrophy were established. Based on these criteria, the rate of positive ECG in different series was rather high, between 8% and 19% [8, 19, 26].

In 2010, the ESC released new recommendations about the ECG interpretation in athletes [27]. The main objective was to differentiate between common, physiologic, ECG changes not necessitating subsequent examinations, and uncommon, pathological, ECG changes requiring further examinations (table 3). The common ECG changes are training-related and result from the physiological adaptation of the cardiac autonomic nervous system and the ventricular myocardium to athletic conditioning. They are more common in black males, in endurance sports and at a high level of training and are present in up to 80% of athletes [27]. Athletes exhibit an increased vagal tone and a decreased sympathetic activity. This results in sinus bradycardia, sinus arrhythmia, ectopic atrial rhythm, first-degree and sometimes Wenckebach second-degree atrio-ventricular block. These changes are easily reverted with activation of the sympathetic nervous system, for instance by quickly standing up. Only when accompanied by symptoms, or profound and out of proportion for the level of training, they need to be distinguished from organic pathologies. Athletic conditioning is associated with morphological cardiac changes with increased cavity dimensions, wall thickness and

Table 3

European Society of Cardiology 2010 classification of ECG abnormalities in athletes. (From [27]: Corrado D, Pelliccia A, Heidbuchel H, Sharma S, Link M, Basso C, et al. Section of Sports Cardiology, European Association of Cardiovascular Prevention and Rehabilitation. Recommendations for interpretation of 12-lead electrocardiogram in the athlete. Eur Heart J. 2010;31:243–59. © 2012, reprinted with permission from Oxford University Press, Oxford, UK.)

Group 1 (training-related)	Group 2 (training-unrelated)
Sinus bradycardia	T-wave inversion
First-degree AV block	ST-segment depression
Incomplete RBBB	Pathological Q-waves
Early repolarisation	Left atrial enlargement
Isolated QRS voltage criteria for LVH	Left axis deviation/ left anterior hemiblock
	Right axis deviation/ left posterior hemiblock
	Right ventricular hypertrophy
	Ventricular preexitation
	Complete LBBB or RBBB
	Long QT or short QT interval
	Brugada-like early repolarisation

LVH = left ventricular hypertrophy; LBBB = left bundle branch block; RBBB = right bundle branch block.

ventricular mass. These changes, associated with the thinness of the athletes, often manifest as an isolated increase of QRS amplitude fulfilling the voltage criteria for left ventricular hypertrophy, which, in absence of other ECG criteria of left ventricular hypertrophy, is not considered pathologic. The above-mentioned structural remodelling of the right ventricle is considered responsible for the incomplete right bundle branch block pattern frequently seen in athletes (fig. 1). Early repolarisation (ER) is traditionally considered a normal ECG variant, more frequent in athletes and modulated by autonomic influences ("sign of good health"). In right precordial leads, ER is almost universally present in males [27]. Recently, ER in inferolateral leads has been linked to idiopathic ventricular fibrillation and, in population studies, with an increased risk of cardiac death, particularly for some ECG phenotypes (inferior leads, horizontal/descending ST segment, particularly with J wave >2 mm), also called "malignant ER" [28, 29]. This has raised concern about potential risks in the athletic population. In our study [30], the prevalence of ER in the inferolateral leads was 36% and the prevalence of "malignant ER" was 8%, respectively 2% when only the most "at risk" phenotype was considered (fig. 2). As pointed out [28], population studies cannot be applied to young healthy athletes and particular care should be taken before drawing conclusions about risk stratification in this young healthy population.

The uncommon ECG changes are unrelated to training, they may represent an underlying cardiovascular disease and warrant further work-up to confirm or exclude it [27]. They include repolarisation abnormalities, conduction abnormalities, voltage criteria for atrial and right ventricular enlargement, axis deviation, abnormal Q-waves, pre-excitation and elements for channelopathies including for the first time short QT interval and Brugada-like pattern. Aiming at maintaining good sensitivity, the ESC 2010 criteria are in some aspects very cautious; therefore, strictly applying

Figure 1

Representative examples of common, training-related ECG changes in athletes.

A Sinus bradycardia with 42 bpm, voltage criteria for left ventricular hypertrophy, early repolarisation in lateral leads.

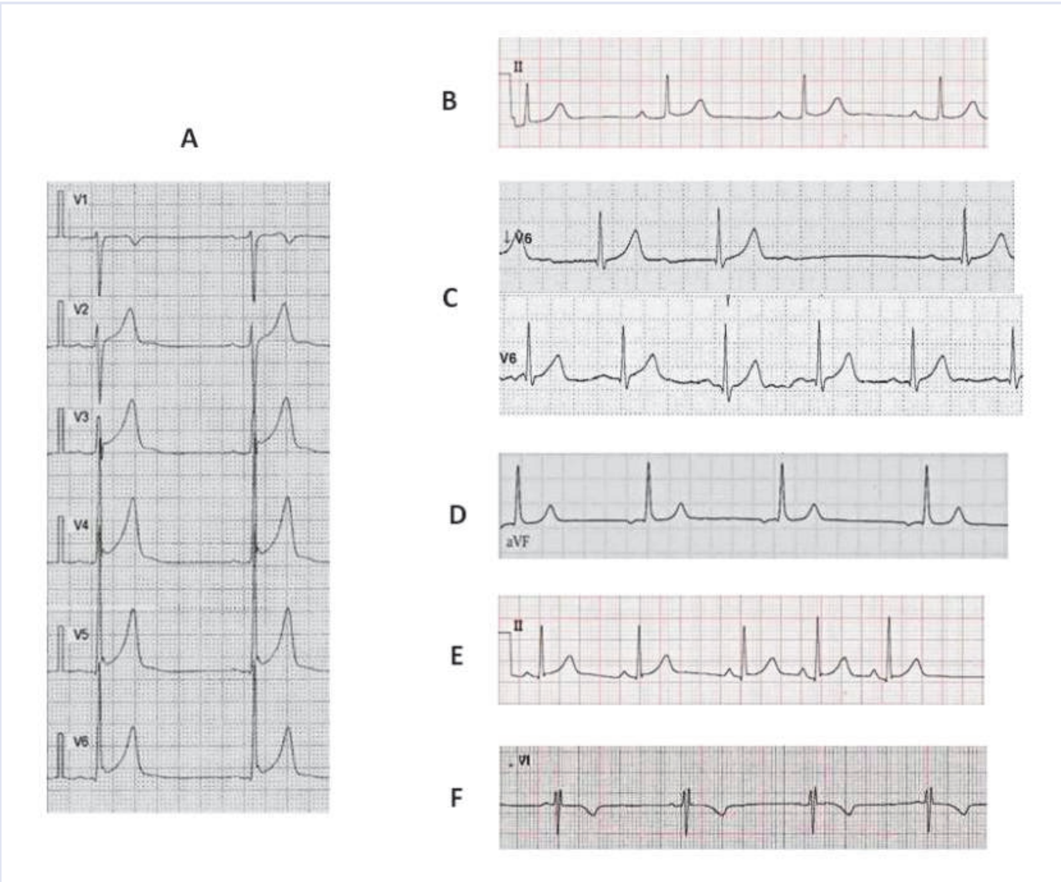
B First-degree atrio-ventricular block with PR 280 msec.

C Wenkeback second-degree atrio-ventricular block (trace above) with prompt reversal after standing up (trace below).

D Ectopic atrial rhythm.

E Sinus arrhythmia.

F Incomplete right bundle branch block.



them results in a considerable number of pathologic ECG varying from 6% to 34% in different series [20, 27, 31–33]. This high variability is likely explained by a variable adherence to the ESC criteria on the basis of the local experience in different centres.

In 2011, a group of American experts published new criteria for the interpretation of the ECG in young athletes [34]. In comparison with the ESC 2010 criteria, these defined ECG abnormalities more restrictively with the consequence that a lower proportion of ECGs would be considered abnormal. The differences concerned mainly T-wave abnormalities, long and short QT interval, Brugada ECG-pattern and voltage criteria for right ventricular hypertrophy (RVH) (table 4). Moreover, considerations about premature ventricular contractions were proposed, an issue not addressed by the ESC 2010 recommendations. We briefly review these American criteria compared to the ESC 2010 criteria; the detailed discussion about the rationale behind them is beyond the scope of this article.

T-wave

ESC 2010 consider T-wave as abnormal if flat or inverted in leads other than V_1, III, aVR. Two relatively frequent situations would be considered abnormal: flat T-wave in aVF and inverted T-wave in right precordial leads in adolescents. The American criteria consider T-wave inversion as abnormal if ≥1 mm, in right precordial leads beyond V_2 (V_3 in females <25 years) in consideration of the juvenile pattern. In a study by Papadakis et al. in adolescent athletes [35], T-wave inversion in right precordial leads was relatively frequent and no cardiomyopathies were discovered; they proposed only T-wave inversion beyond V_2 if aged ≥16 years or deep T-wave inversion to be considered abnormal. Moreover in black athletes, T-wave inversion following an ER pattern in V_1–V_4 is frequent and should not be considered abnormal [36].

Long and short QT interval

ESC 2010 propose a QTc (Bazett) limit of 440 msec for males and 460 msec for females for long QT interval and 380 msec for short QT interval. It is known that there is considerable overlap between a normal population and an affected one [22]. However, for the purpose of screening and considering that athletes could have longer QTc [37], it appears that these values, especially for males, are very restrictive: in a study of

Figure 2

Examples of early repolarisation (ER) in athletes.

A ER in right precordial leads with concave ascending ST segment, a pattern almost constant in males.

B ER in right precordial leads with convex ascending ST segment, a pattern frequently encountered in black athletes, sometimes followed by terminal negative T-wave up to V_4.

C ER in infero-lateral leads. The most frequent phenothype in athletes is in lateral leads with notch J wave and ascending ST segment.

D ER in infero-lateral leads with “malignant phenothype”: horizontal/descending ST segment in the inferior leads, J wave >2 mm.

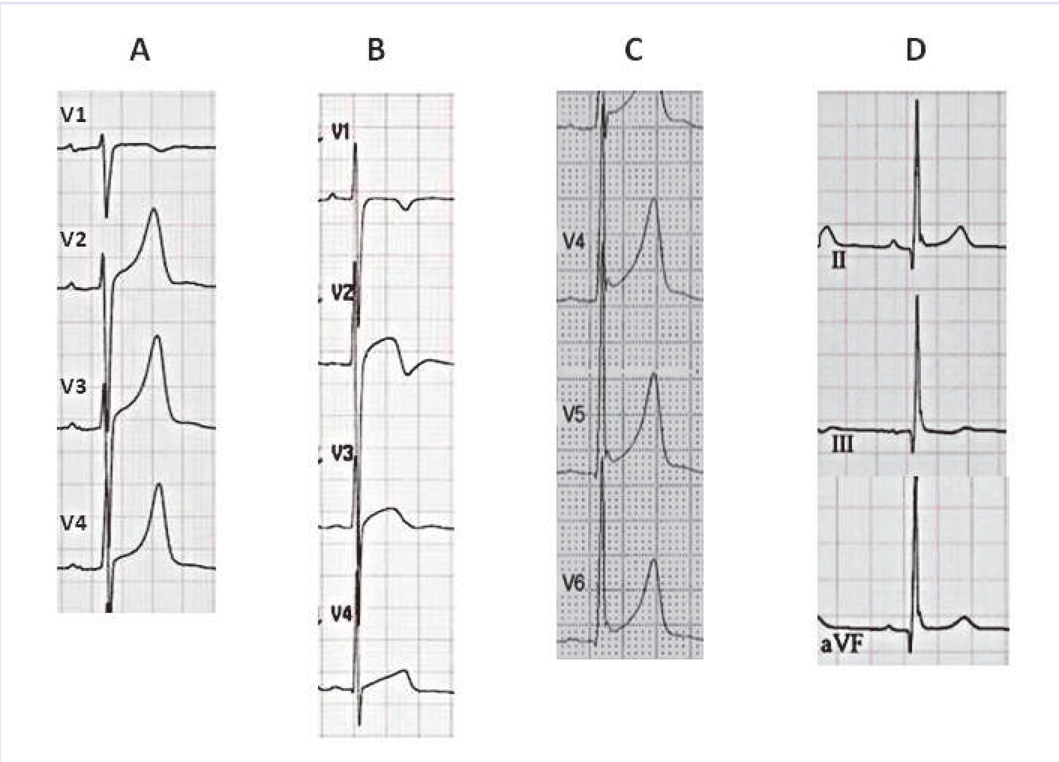


Table 4
Main differences between European Society of Cardiology (ESC) 2010 and American 2011 criteria for ECG abnormalities in athletes (modified from [27, 34]).

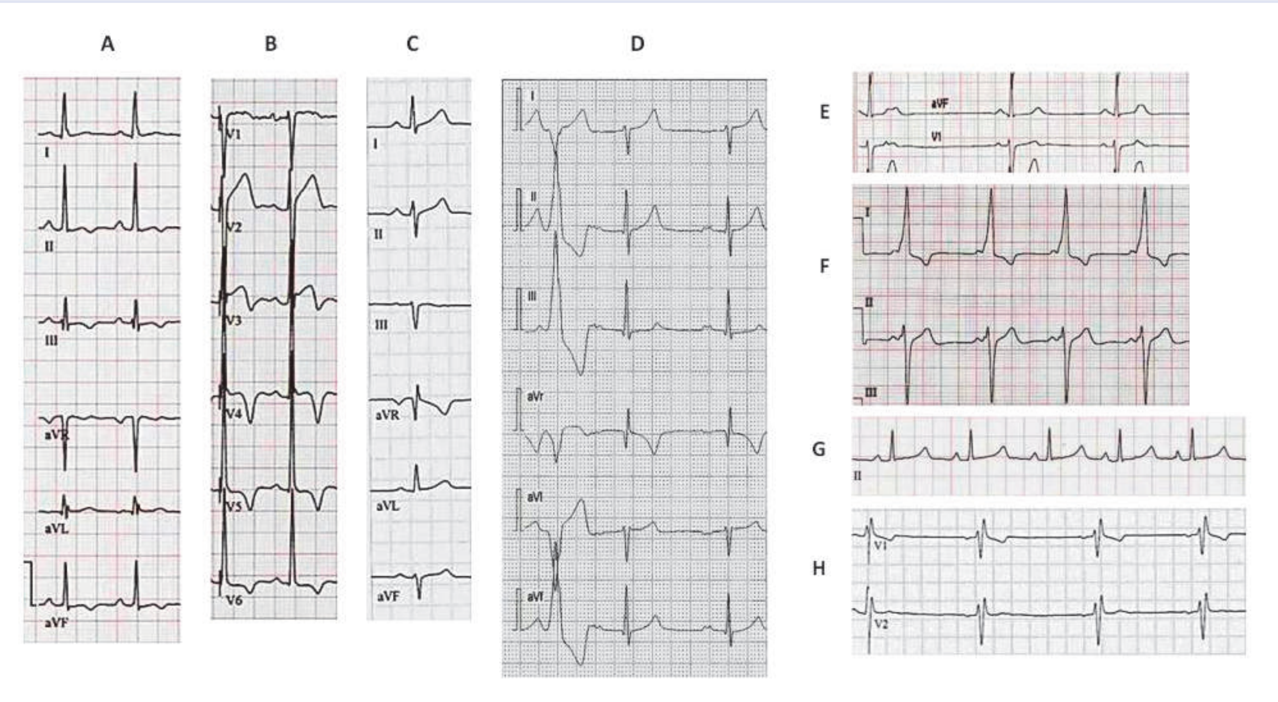
	ESC 2010	American 2011
T-wave abnormalities	Flat or negative T-waves in leads other than V_1, aVR, III	≥1 mm T-wave inversion in leads other than V_1/V_2 (V_3 in females <25 y.o), aVR, III. Exception: black athletes with neg. T-waves V_1–V_4 after early repolarisation.
Long QT interval (QTc, msec)	Males >440, females >460	Males >470, females >480
Short QT interval (QTc, msec)	<380	<340
Brugada	Brugada-like early repolarisation	Brugada type 1
Right ventricular hypertrophy (RVH)	Voltage criteria	<30 years: voltage criteria and other ECG criteria of RVH >30 years: voltage criteria
Premature ventricular beats	Undefined	≥2 per standard ECG

41,767 Swiss conscripts [38], 2% had QTc ≥440 and would be considered abnormal. The proposed values of 470 msec in males and 480 msec in females in the American criteria seem to significantly increase specificity without losing sensitivity, at least for subjects at higher risk. Concerning short QT interval, a very rare condition, the published cases generally have QTc <320–340 msec [39]. The ESC limit at 380 msec seems too high. A QTc limit of 340 msec as indicated in the American criteria is in line with the current knowledge.

Brugada ECG-pattern

ESC 2010 criteria stated that Brugada-like pattern should be further investigated with special emphasis in distinguishing a Brugada pattern from an ER pattern. Brugada type 2 and 3 (not diagnostic) is not so rare in athletes, being observed in 0.5–1% [40, 41]. It is even more frequent when V_1 and V_2 are recorded in the third intercostal space (known to enhance the sensitivity to detect this pattern): 4.1–8.4% [40, 41]. Given the good prognosis of Brugada type 2 or 3 in asymptomatic

Figure 3
Representative examples of pathological ECG in athletes.
A Minor T-wave inversion in inferior leads.
B Deep T-wave inversion in anterolateral leads.
C Left axis deviation.
D Right axis deviation, left atrial enlargement, premature ventricular contraction.
E Premature atrial contractions.
F Wolff-Parkinson-White pattern.
G Long QT interval (QTc 485 msec).
H Complete right bundle branch block.



subjects and since there is no evidence for additional prognostic value in subjects tested for conversion into diagnostic type 1 [42], it seems reasonable, as suggested by the American criteria, to repeat ECG on a yearly basis (to check for spontaneous conversion into type 1) and to manage these athletes conservatively, with prompt reevaluation in case of syncope.

Voltage criteria for RVH

Voltage criteria for RVH are fulfilled in up to 14.5% of athletes [25, 43, 44]. There are no solid data on the link between these criteria, when isolated, and right ventricular pathologies, especially for young people and for athletes. A recent report showed a very low correlation with right ventricular hypertrophy in athletes [43]. Therefore, in accordance with the American criteria, isolated voltage criteria for right ventricular hypertrophy should not be considered abnormal in young athletes.

Premature ventricular contractions (PVC)

A recurrent question relates to ECGs with ≥1 PVC. According to the American criteria an ECG is considered abnormal when ≥2 PVC are present. It should be stressed that a 10 second ECG with 1 PVC could mean 8,640 PVC/day. In our practise, when faced with 1 PVC, we monitor the subject for about 1 minute; if PVC recur, then we proceed with further exams. We have the same approach for premature atrial contractions (PAC). Doing so, 0.6% and 0.5% of our athletes had abnormal PVC and PAC, respectively [44].

It should be clear from the above that the criteria used to define the abnormal ECG determine which proportion of ECGs are considered abnormal and therefore which proportion of athletes will be submitted to further examinations. In our study of 1,070 athletes, we utilised the ESC 2010 criteria adapted according to the aforementioned points. These modified criteria were very similar to the American ones that were published after the beginning of our study. Overall 3.9% of our athletes [44] had an abnormal ECG (fig. 3), a number favourably comparing to centres with longstanding experience in this field and which apply selective ECG criteria [9].

Based on review of the literature and on our experience, we recommend that the American criteria be adopted for the ECG interpretation of young athletes; they represent in our opinion the best balance between sensitivity and specificity.

There are ongoing efforts to find more specific criteria for the ECG interpretation of athletes: a recent report [45] demonstrated that axis deviation and voltage criteria for atrial abnormalities have low diagnostic yields and it was proposed to exclude them from the definition of abnormal findings, thus making ECG criteria even more specific.

Costs of screening

As mentioned above, costs represent the main issue of a cardiac screening programme. They depend on the costs of the health system and on the total number of examinations performed, which in turn depend largely on the number of abnormal ECGs. In Switzerland the costs of a screening cardiovascular examination in athletes are not reimbursed by the insurances and must be covered by the athlete himself or by the club. There are no data on the total real costs of such a programme. In Italy the costs for the screening and the subsequent examinations are estimated at 36 Euros per athlete, but this represents, in our opinion, a significant underestimation [46]. In the Unites States the total costs of a screening programme with ECG are estimated at 374 US Dollars per athlete [26]. In our study [21], we calculated the costs of the screening and the subsequent examinations performed for each athlete according to the current Swiss medical fees (TARMED). The average cost per athlete was 138 Swiss Francs. In our opinion this represents a definitely sustainable price especially when compared to the expenses of other cardiac procedures that are performed more and more often.

Conclusions and personal view

In conclusion, based on the data of the literature and our experience, we warmly recommend that young athletes undergo a cardiovascular screening with ECG. This should be done by physicians with considerable specific clinical experience, and applying rigorous ECG criteria. Only in this way the screening can be realised with few subsequent examinations and, accordingly, at low costs, allowing its large-scale implementation. Otherwise, it could generate an explosion of examinations, costs, anxiety and inappropriate diagnoses. Moreover, when dealing with young athletes, disqualification should be advised only when based on proven diagnoses, since an unnecessary forced interruption of sport participation could have devastating psychological consequences.

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