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Pre-participation screening in the young competitive athlete: International recommendations and a Canadian perspective

Although evidence supports the use of an electrocardiogram in cardiovascular screening programs for athletes, there are still concerns about feasibility and cost-effectiveness.

ABSTRACT: The sports medicine and cardiology communities have debated the role of screening ever since publication of a 25-year longitudinal study in Italy showed an 89% reduction in the rate of sudden cardiac death in young athletes after a cardiovascular screening program was implemented. Several consensus statements and research trials have been published on the effectiveness of screening young athletes, with the primary point of debate being whether the resting 12-lead electrocardiogram should be included, primarily due to concerns about false-positive rates and cost-effectiveness. Little research has come out of Canada on this topic, and to date no official recommendations have been developed for screening in this population.

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The sudden cardiac death (SCD) of a young athlete is typically the result of structural and arrhythmic disorders that go undiagnosed, as the conditioned athlete typically doesn't exhibit symptoms.[1] As a result, medical organizations such as the American Heart Association (AHA) and the European Society of Cardiology (ESC) have published recommendations for the routine pre-participation screening of young competitive athletes. The AHA recommends cardiovascular screening for high school and college athletes before athletic participation and at 2-year to 4-year intervals thereafter.[2] This initial screening consists of a cardiovascular-focused history and physical examination. The ESC endorses routine pre-participation screening of athletes with a history and physical examination, but also recommends adding a resting 12-lead electrocardiogram (ECG).[3] The AHA's rationale for not including an ECG are multifactorial and include concerns about false-positive results, cost-effectiveness, physician infrastructure, and the feasibility of using health care resources for large-scale ECG screening.[4]

Currently, Canada has no official mandate or internationally recognized recommendations for pre-participation screening in young competitive athletes.

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Unanswered questions

To date, no randomized trials have compared various pre-participation screening methods. The strongest data demonstrating a mortality reduction in routine screening are from a prospective cohort study in Veneto, Italy, that has formed the basis for the European Society of Cardiology support of routine screening of athletes with ECGs.[3] Indeed, several studies suggest that using an ECG as an adjunct to history and physical examination increases sensitivity and specificity.[3,5,6] In contrast, the American Heart Association supports screening in selected athletes only and without the use of a 12-lead ECG.[2,7] The different approaches stem mainly from a debate about the true incidence of SCD and concerns about the cost-effectiveness of testing. Some expert opinion and data even suggest that a systematic screening program is not justified based on the low incidence of SCD in young athletes. In Minnesota, forensic case records were investigated over a 26-year period (1986 to 2011) to determine the incidence and causes of SCD in high school athletes.[8] The incidence of SCD was found to be 0.7 per 100 000 person-years and it was determined that only 31% of the cases would have been reliably identified by a screening program that required a history, a physical examination, and an ECG.

Screening recommendations

Italy has legally mandated routine screening for young competitive athletes since 1982,[7] and the ESC guidelines are based on the same observational study used to support the Italian law.[1] This population-based study looked to determine the impact of pre-participation screening on trends in SCD in athletes and nonathletes age 12 to 35 years studied between 1979 and 2004, totaling 2 938 730 person-years of observation. Screening included family and personal history, a physical examination, and a resting 12-lead ECG. The rate of SCD among athletes was found to be 3.6 per 100 000 person-years before screening. Following 26 years of screening, the rate decreased to 0.4 per 100 000 person-years, an 89% relative risk reduction. During this same period, the rate of SCD among nonathletes was unchanged at approximately 0.8 per 100 000 person-years. Most of the mortality reduction was observed in patients with cardiomyopathy, in particular arrhythmogenic right ventricular cardiomyopathy (ARVC), which was expected given the high prevalence of the condition in the study population. Approximately 9% of athletes had positive findings on initial screening, and 2% of athletes were found to have actual heart disease. The study authors concluded that the reduction in SCD incidence was due to the implementation of the screening program in 1982.

In 1997 Israel also implemented a mandatory pre-participation screening program that required all athletes engaged in a sporting activity at any level of physical endurance to complete a medical questionnaire, physical examination, baseline ECG, and exercise stress test.[9] Upon investigation of the program, there was a marked year-to-year variation in sudden death rates, with the highest being 2 years before the screening mandate (8.4 deaths/100 000 person years). Comparing mortality 2 years prior to screening with mortality at the end of the study, the authors drew a conclusion similar to that of the Italian study: screening is extremely effective for preventing SCD among athletes. However, when the entire study was reviewed and data compared for the decade before screening (2.54 events/100 000 person-years) and the decade after screening (2.66 events/100 000 person-years) it appears that the mortality reduction was most likely related to a large year-to-year variation. These results suggest that screening with resting and exercise ECGs had no influence on the incidence of sudden death in athletes. Subsequently, the Israeli study has been criticized for methodological limitations—primarily the collection of SCD data from two Israeli newspapers rather than from a prospective registry.[10]

In 1973 Japan initiated a national screening program to detect cardiovascular disease in adolescents. The screening began in grade 7 with a 3-year follow-up. Both a questionnaire and ECG were used to screen athletes and nonathletes. A study of the program was conducted between 1989 and 1997 and the authors found the screening to be cost-effective ($8800/year of life saved) and useful in identifying hypertrophic cardiomyopathy (HCM) and reducing SCD.[11] However, over the course of the study only 9 out of 37 807 subjects were identified as high-risk (i.e., found to have cardiovascular disease) and restricted from activity. The authors concluded that a nationwide registry that includes autopsies for all sudden deaths should be undertaken.

The AHA consensus scientific panel has consistently argued against nationally mandated routine pre-participation screening with a 12-lead ECG and has specifically raised concerns about the data from Italy.[2,7] Firstly, the Italian study did not compare athletes who underwent screening with those who did not. Secondly, the data were generated from a population-based observational study, meaning that management of the athletes could have contributed to the improved outcomes. Thirdly,

Table 1. American Heart Association (AHA) and European Society of Cardiology (ESC) recommendations for history and physical examination in cardiovascular screening of competitive athletes.

	AHA	ESC
Personal history	1. Chest pain/discomfort/tightness/pressure related to exertion 2. Unexplained syncope/near syncope (judged not to be vasovagal; particularly concerning when occurring during exercise) 3. Excessive and unexplained dyspnea/fatigue or palpitations, associated with exercise 4. Prior recognition of a heart murmur 5. Elevated systemic blood pressure 6. Prior restriction from participation in sports 7. Prior testing for the heart, ordered by a physician	1. Exertional chest pain or discomfort 2. Syncope or near-syncope 3. Shortness of breath or fatigue out of proportion to the degree of physical effort 4. Palpitations or irregular heartbeat
Family history	8. Premature death (sudden and unexpected, or otherwise) before 50 years of age attributable to heart disease in ≥ 1 relative 9. Disability from heart disease in close relative < 50 years of age 10. Hypertrophic or dilated cardiomyopathy, long QT syndrome, or other ion channelopathies, Marfan syndrome, or clinically significant arrhythmias; specific knowledge of genetic cardiac conditions in family members	5. Close relative(s) with premature myocardial infarction or sudden death at < 55 years (male), < 65 years (female) 6. Family history of cardiomyopathy, coronary artery disease, Marfan syndrome, long QT syndrome, severe arrhythmias, or other disabling cardiovascular diseases
Physical examination	11. Heart murmur (likely to be organic and unlikely to be innocent; auscultation should be performed with the patient in both the supine and standing positions or with Valsalva maneuver specifically to identify murmurs of dynamic left ventricular outflow tract obstruction) 12. Femoral pulses to exclude coarctation 13. Physical stigmata of Marfan syndrome 14. Brachial artery blood pressure (sitting position), preferably taken in both arms	7. Heart murmurs (systolic grade ≥ 2/6 and any diastolic) 8. Mid- or end-systolic clicks 9. Abnormal second heart sound (single or widely split and fixed with respiration) 10. Irregular heart rhythm 11. Diminished and delayed femoral artery pulses 12. Musculoskeletal and ocular features suggestive of Marfan syndrome 13. Brachial blood pressure ≥ 140/90 mm Hg on more than one reading

the study did not compare screening performed with an ECG to screening without an ECG. Finally, potential differences may have existed within the study populations: the athletes undergoing screening were from Padua Center for Sports Medicine, whereas the comparison population consisted of subjects from the larger Veneto region.

The AHA position has been strengthened by results of an analysis comparing Italian athletes undergoing routine screening with a 12-lead ECG and American athletes undergoing no formal screening.[12] No difference was found in annual mortality rates from 1993 to 2004 (0.87 Italian deaths vs 0.93 American deaths per 100 000 athletes, $P = .88$),[12] leading the authors to conclude that SCD in young trained athletes is a rare event that pre-participation screening is unlikely to eliminate, regardless of the strategy used.

History and physical examination

As summarized by a consensus paper that includes a 14-element evaluation process,[7] the AHA recommends a cardiovascular-focused personal history, family history, and physical examination. The ESC recommendations for a history and a physical examination are similar, but differ regarding the inclusion of coronary artery disease in the family history and more specific details about heart murmurs in the physical examination (**Table 1**).[3]

Sensitivity has been reported to be a concern with the use of history and physical examination, as shown in a report of 115 cases of SCD where the cardiovascular abnormality responsible for sudden death was identified in only one athlete of all those screened (0.9%).[13] High false-positive rates have also been an issue in screening with history and physical examination. Ullah and colleagues examined 15 027 individuals age 14 to 35 over a

5-year period using a personal symptom and family history questionnaire as well as a resting 12-lead ECG. The false-positive rate reported for symptoms identified by the questionnaire was 36.0%, whereas it was only 7.4% for the ECG.[5]

Although a personal symptom and family history questionnaire is certainly a necessary part of any proposed screening protocol, the effectiveness of a questionnaire used on its own must be questioned given that sudden death is the first clinical manifestation for 60% to 80% of athletes with underlying cardiac disease.[6]

Considerations for routine use of resting 12-lead ECG

ECGs may be particularly useful in patients with structural heart disease. Athletes typically exhibit ECG abnormalities if they have HCM (95%) or ARVC (80%), while a normal ECG has a high negative predictive value (99.98%), essentially excluding HCM in athletes.[6]

In Italy, Corrado and colleagues found that the ECG had a 77% greater power to detect HCM than history and physical examination alone.[6] The ECG has also been proven effective in identifying patients with Wolff-Parkinson-White syndrome and the majority of patients with channelopathies.[14] In a recent meta-analysis of the effectiveness of screening for underlying cardiovascular disorder in athletes using ECG, history, and physical examination, the sensitivity and specificity for each screening tool were 93% and 94% for ECG, 20% and 94% for history, and 9% and 97% for physical examination.[15] These studies support the current recommendations of the ESC and the International Olympic Committee.[3,16]

One limitation of ECG use is that trained athletes with structurally normal hearts often have abnormal ECG findings when compared with the general population. Sinus bradycardia, sinus arrhythmia, first-degree atrioventricular (AV) block, incomplete right bundle branch block, early repolarization, and isolated QRS voltage increase criteria for left ventricular hypertrophy are all common among athletes.[17] False-positive findings resulting from the application of standard ECG criteria to the interpretation of athlete ECGs have led to a highly variable rate of secondary testing (8% to 15%).[18] In response, guidelines and criteria have been developed to reduce the need for unnecessary additional testing (**Table 2**).[19-22]

To assess how effective the 2010 ESC criteria are for interpreting the 12-lead ECG in the athlete, Drezner and colleagues[21] asked 60 physicians to interpret 40 ECG results; 28 results from National Collegiate Athletic Association (NCAA) Division 1 athletes without abnormalities were randomized with 12 results from individuals with known cardiovascular pathology. Each physician was asked to interpret the ECG results without referring to guidelines and then again using the 2010 ESC criteria. The diagnostic accuracy of sports medicine physicians improved from 78% to 91% and that of cardiologists improved from 85% to 86%. Overall the specificity of the diagnoses improved from 70% to 91% and the sensitivity improved from 89% to 94% in these groups.

Since the release of the 2010 ESC criteria, further revisions in the form of the Seattle criteria have improved sensitivity.[20] Investigators out of Australia performed cardiovascular screening on 1078 elite athletes between age 16 and 35. Both the ESC and Seattle criteria for ECG interpretation were used to assess athletes. The Seattle criteria were found to reduce the false-positive rate of ECG screening from 17.1% to 4.2% while still identifying all athletes later found to have a cardiovascular abnormality upon follow-up investigation.[22]

These findings suggest that if a systematic screening program were to be implemented in Canada, it would be reasonable to include the resting 12-lead ECG in order to improve sensitivity. As further data are obtained and more studies are conducted, criteria for interpretation will continually be adjusted and improved.

Echocardiography in athlete screening

Echocardiography is a sensitive and specific noninvasive diagnostic test for multiple conditions known to predispose athletes to SCD. Hypertrophic cardiomyopathy, the leading cause of SCD in young competitive athletes in the US, is easily characterized on an echocardiogram revealing a hypertrophied nondilated left ventricle and a ventricular septum that is markedly thickened when compared with the posterior left ventricular wall. An echocardiogram can also reveal other causes of SCD such as congenital aortic stenosis, dilation of the ascending aorta related to Marfan syndrome, and dilated cardiomyopathy.[23] However, the echocardiogram is a time-consuming and expensive test, making it impractical for use in a publicly funded screening program. Most studies have used this highly sensitive diagnostic test as a follow-up test to the ECG or personal history and family questionnaire.

In an attempt to assess the effectiveness of incorporating an echocardiogram in the screening process, researchers from Indianapolis employed a limited "screening" echocardiogram (parasternal long- and short-axis two-dimensional views), along with history and physical examination.[24] They reported the cost for technician salaries, supplies, interpre-

Table 2. Distinguishing between normal and abnormal ECG findings in the athlete using 2010 European Society of Cardiology (ESC) criteria and the Seattle criteria (measurement parameters not included).

Normal ECG findings		Abnormal ECG findings	
2010 ESC criteria	**Seattle criteria**	**2010 ESC criteria**	**Seattle criteria**
Sinus bradycardia	Sinus bradycardia	T wave inversion	T wave inversion
Sinus arrhythmia	Sinus arrhythmia	ST segment depression	ST segment depression
Junctional escape rhythm	Junctional escape rhythm	Pathological Q waves	Pathological Q waves
First-degree atrioventricular (AV) block	First-degree AV block	Right ventricular hypertrophy	Right ventricular hypertrophy pattern
Second-degree Mobitz type I (Wenckebach) AV block	Second-degree Mobitz type I (Wenckebach) AV block	Ventricular pre-excitation	Ventricular pre-excitation
Incomplete right bundle branch block (RBBB)	Incomplete RBBB	Complete left bundle branch block (LBBB) or RBBB	Complete LBBB
Early repolarization	Early repolarization (ST elevation, J point elevation, J waves, or terminal QRS slurring)	Long or short QT interval	Long or short QT interval
Isolated QRS voltage criteria for left ventricular hypertrophy (LVH)	Isolated QRS voltage criteria for LVH **Exception:** QRS voltage criteria occurring with any nonvoltage criteria such as left atrial enlargement, left axis deviation, ST segment depression, T wave inversion, or pathological Q waves	Brugada-like early repolarization	Brugada-like ECG pattern
	Ectopic atrial rhythm	Left atrial enlargement	Left atrial enlargement
	Convex ("domed") ST segment elevation combined with T wave inversion in leads V1 to V4 in black/African athletes	Left axis deviation/left anterior hemiblock	Left axis deviation
		Right axis deviation/left posterior hemiblock	Intraventricular conduction delay
			Profound sinus bradycardia
			Atrial tachyarrhythmia (supraventricular tachycardia, atrial fibrillation, atrial flutter)
			Premature ventricular contractions
			Ventricular arrhythmias (couplets, triplets, and nonsustained ventricular tachycardia)

tation, and machine rental to be less than $14 per echocardiogram. However, this estimate does not include overhead expenses or infrastructure purchases, and uses a rate of $60 per hour for echocardiogram interpretation. This figure is highly unrealistic in Canada where physicians bill MSP for individual test interpretations.

While handheld echocardiography is being used increasingly in clinical settings for a quick assessment of cardiac structure and function, using it for primary testing is unlikely because a highly competent and trained expert (i.e., an experienced cardiologist) must administer the test.[25] Handheld echocardiography is also unlikely to be cost-effective in screening athletes, and full echocardiography should be used only when the history, physical examination, or ECG indicates the need for further investigation.

Cost-effectiveness of screening

There are major discrepancies in terms of estimated costs of screening across countries. The Italian screening program is estimated to save approximately four lives per 100 000 person-years.[1] This translates into one life saved per 25 000 individuals screened in a given year at a cost of approximately €1 000 000.[26] Assuming that young competitive athletes will live at least another 20 years, the cost per year of life saved can be estimated at approximately €50 000. This cost estimate does not include screening infrastructure, which is already in place in Italy, and need-

ing to provide such infrastructure would certainly drive up the cost of starting a completely new program. In contrast, screening costs estimated for the United States have ranged from $44 000 per year of life saved if screening high school athletes by ECG, to an AHA estimate of $3.4 million to prevent each theoretical death if screening by history, physical examination, and ECG.[2,23]

According to AHA estimates, it would cost $330 000 to detect each athlete with relevant cardiac disease, resulting in a $2 billion annual cost and $3.4 million for each death prevented.[2] However, this estimate is based on annual testing for 10 million student athletes and a cost of $50 per ECG, and it has been suggested that a negotiated cost for mass screening could be as low as $10 per ECG.[2,27]

In a detailed and comprehensive cost-effectiveness evaluation of cardiovascular screening in the young competitive athlete, Wheeler and colleagues found an incremental cost-effectiveness ratio of $199 000 per life-year saved for screening with history and physical exam versus no screening, and an incremental cost-effectiveness ratio of $76 100 per life-year saved for screening with ECG plus history and physical examination versus no screening.[28]

To date, most cost-effectiveness analyses on cardiovascular screening in the young competitive athlete show the inclusion of the ECG to be cost-effective.[11,23,28] The discrepancies are due to disparities in methodology, variation in baseline statistics used for SCD incidence, and false-positive rates, as well as differences in the assigned cost for ECG and additional cardiovascular evaluations.

To date, most cost-effectiveness analyses on cardiovascular screening in the young competitive athlete show the inclusion of the ECG to be cost-effective.

More outcome-based research needed

Evidence for cardiovascular screening in the young competitive athlete and the effectiveness of screening tools has relied on varying data. What seems to be consistent, however, is the evidence supporting an increase in the sensitivity of a screening program that includes an ECG. While the AHA acknowledges this, they continue to recommend against systematic screening with ECG because of concerns about feasibility and cost-effectiveness.

In order to make appropriate health care decisions for Canada's athletes and develop effective strategies for prevention, we need to accurately assess the prevalence of disorders that contribute to SCD in Canada and to determine the true incidence of SCD, ideally through the development of a nationwide registry.

Although researchers in the specialized field of sports cardiology have been gathering data in the United States and Europe, Canada cannot rely on this data alone to understand the role of pre-participation screening in young athletes, given our country's unique and ethnically heterogeneous population. Also, while sports cardiology is a growing international discipline, in Canada the subspecialty is very much in the nascent stage. Research is underway, however, as evidenced by two retrospective studies out of Ontario focusing on the underlying causes and incidence of sudden cardiac death using coroner reports.[29,30] In order for any recommendations to be made for a Canadian screening program, many more prospective observational, randomized controlled, and longitudinal studies must be conducted to assess epidemiological and economic factors affecting the viability and effectiveness of such a program.

Competing interests

None declared.

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