Efficacy of personal symptom and family history questionnaires when screening for inherited cardiac pathologies: the role of electrocardiography

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ABSTRACT

Aims: This study sought to confirm the efficacy of using resting 12-lead ECG alongside personal symptom and family history questionnaires and physical examination when screening for diseases with the potential to cause sudden cardiac death in the young.

Methods and results: 1074 national and international junior athletes (mean age 15.8 (SD 0.7) years, range 10 to 27) and 1646 physically active schoolchildren (16.1 (SD 2.1) years, range 14 to 20) were screened using personal and family history questionnaires, physical examination and resting 12-lead ECG. Nine participants with a positive diagnosis of a disease associated with sudden cardiac death were identified. None of the participants diagnosed with a disease associated with sudden cardiac death were symptomatic or had a family history of note.

Conclusion : Family history and personal symptom questionnaires alone are inadequate to identify people with diseases associated with sudden cardiac death. Use of the 12-lead ECG is essential when screening for cardiac pathology in the young.

The death of a young athletic person is a tragic and highly publicised event that causes great debate within the general public, as exercise is viewed as being very beneficial for general health. Sudden cardiac death in athletes can largely be attributed to a number of inherited or congenital cardiac pathologies, including hypertrophic cardiomyopathy (HCM), arrhythmogenic right ventricular cardiomyopathy (ARVC), idiopathic concentric left ventricular hypertrophy, congenital anomalous coronary arteries, Wolff–Parkinson–White syndrome (WPWS), long QT syndrome and Marfan syndrome,[1] and raises the question of the usefulness of cardiovascular screening to identify pathology.[2–8] The purpose of pre-participation screening is to provide medical clearance for participation in sport through routine systematic evaluations intended to identify pre-existing cardiovascular abnormalities and thereby reduce the potential for adverse events and loss of life.[2]

Several major organisations (International Olympic Committee Medical Commission;[9] European Society of Cardiology[3] and the Fédération Internationale de Football Association (FIFA)[10]) have recently released consensus statements recommending a common world and European screening protocol based on a 12-lead ECG, personal and family history questionnaires, and physical examination. These consensus statements have been broad-ranging, from elite Olympic athletes to general population sport screening.

Echocardiography is generally accepted as the "gold standard" method of assessment within cardiac screening programmes, owing to its ability to diagnose HCM, the commonest cause of sudden cardiac death (SCD) in young athletes.[1] Furthermore, there is controversy within the sports medicine community about the sensitivity of electrocardiography. In particular, ECG alterations are commonly observed in athletes as normal variants of athletic training,[1] leading some authors to suggest that electrocardiography should be excluded in favour of personal and family history questionnaires.[11] Indeed, the American Heart Association (AHA) consensus guidelines[11] support the sole use of family history questionnaires and physical examination for certification to participate in competitive sport, citing the low cost and practicality.

This study sought to confirm the efficacy of resting 12-lead ECG in addition to personal/family history questionnaires and physical examination as collective tools to identify diseases with potential to cause sudden death within a cohort of elite junior athletes and physically active schoolchildren.

METHODS

Written informed consent was obtained from all participants after ethics approval from Lewisham ethics committee.

Participants

In total, 2720 young people (<35 years of age) were examined between September 2000 and February 2006. These comprised 1074 National and international junior athletes (mean age 15.8 (SD 0.7) years, range 10 to 17) and 1646 physically active schoolchildren (16.1 (SD 2.1) years, range 14 to 20) were screened using personal and family history questionnaires, physical examination and resting 12-lead ECG.

Screening of elite athletes was organised through their team doctors, and the athletes were asked to abstain from all physical activity for at least 3 hours before screening. For the school group, a standard letter was distributed by their school administration inviting students to attend the screening if they were interested in their cardiac health. Participants made appointments with the investigators once they had absorbed and understood the background information about the risks and benefits of an ECG investigation. Parental consent was obtained for children aged <16 years. Participants were not allowed to make the appointment within 48 hours of receiving the

information or without signing the informed consent documents.

Physical examination and questionnaire consultation

Measurement of height (cm), body mass (kg), brachial artery blood pressure in the seated position (mmHg), precordial auscultation in both supine and standing positions, and examination for the physical characteristics of Marfan syndrome was undertaken by a consultant cardiologist with extensive experience of the athlete's heart syndrome and conditions predisposing to SCD in young athletes.

Personal and family history questionnaire

Participants were asked to complete a questionnaire (table 1) before attending the ECG screening. If family history of sudden death or cardiac disease was unknown by the participant, they were asked to investigate with first and second degree relatives until complete. Obtaining this information was problematic for a small number of participants who were either adopted or orphaned at an early age.

The repetition of questions within the questionnaire was an attempt to identify symptoms in different environments to improve sensitivity. The questionnaire was a combination of open and closed questions. After each closed question, participants answered yes or no, but were provided additional space to explain their answer fully, allowing better evaluation by the screening cardiologist. A positive answer to a question was scored as 1 and a negative answer was scored as 0. Total positive answers were tallied separately for each question and split for the athlete and schoolchildren groups with their centile values added.

Athletes with symptoms, and/or abnormalities on physical examination and/or electrocardiographic abnormalities (box 1 and table 2) underwent further detailed cardiovascular investigation with appropriate investigations, which included any one or a combination of echocardiography, 24-hour Holter ECG and integrated exercise cardiopulmonary stress test. Symptoms considered to be suggestive of a possible underlying cardiovascular disorder include repetitive syncope during exercise, prolonged periods of palpitations, sustained chest pain and unexplained sudden death in a first degree relative aged <35 years. Athletes with soft murmurs (grade I) that did not radiate, or who had no electrocardiographic changes, were deemed to have flow murmurs requiring no further action.

Table 1 Personal symptoms and family history questionnaire

Question	Answer	
1 Have you ever fainted?	During exercise	Yes / No
	Following exercise	Yes / No
	Unrelated to exercise	Yes / No
2 Do you experience dizzy turns?	During exercise	Yes / No
	Following exercise	Yes / No
	Unrelated to exercise	Yes / No
3 Do you experience palpitations?	Yes / No	
4 Do you experience chest pain, heaviness or tightness?	During exercise	Yes / No
	Following exercise	Yes / No
	Unrelated to exercise	Yes / No
5 Do you feel that you are more breathless or more easily tired than your team mates?	Yes / No	
6 Is there a family history of heart disease?	Yes / No	
7 Has there been unexplained death or deaths due to heart disease in young family members?	Yes / No	

Box 1 A list of electrocardiography patterns considered to represent a potentially serious cardiac disorder

ECG pattern

- Inverted T waves (more negative than −0.2 mV) in any lead except aVR, V1 and III
- Left ventricular hypertrophy (Romhilt–Estes)
- ST segment depression
- Voltage criteria for increased left atria
- Left axis deviation and one other abnormality
- Pathological Q wave patterns
- Prolonged QT interval
- Epsilon waves
- Right ventricular hypertrophy with ST segment depression in leads V1 to V3
- Complete bundle branch block

Resting 12-lead electrocardiography

On arrival, participants were instructed to lie in a supine position in a quiet room. After 5 minutes' rest, a standard 12-lead ECG (Marquette Hellige, Milwaukee, USA) was used on the subject. The electrodes were placed carefully to ensure consistency of the precordial lead locations. The ECG trace was stored electronically and printed as hard copy for later analysis. All ECG traces were assessed independently by a consultant cardiologist who had full knowledge of the broad spectrum of ECG changes associated with conditions predisposing to sudden cardiac death. PR interval, QRS duration, QT interval, QRS axis, Q, R, S and T wave voltage, and ST segments were measured by each lead. P wave voltage was measured by lead V1 alone. Left axis deviation was defined as a QRS axis more negative than −30°, and right axis deviation as a QRS axis more positive than +120°. The QT intervals were corrected for heart rate (QT_c) using Bazett's formula. A QT_c interval was considered abnormally prolonged if >450 ms in male and >460 ms in female subjects. Right atrial enlargement was defined as a P wave voltage ≥0.25 mV. Left atrial enlargement

Table 2 Positive answers given by junior athletes and schoolchildren to the personal symptom and family history questionnaires

Question	Personal symptoms and family history	Junior athletes (n = 1047)	School children (n = 1646)
1	Have you ever fainted during exercise?	14 (1.3)	55 (3.3)
2	Have you ever fainted following exercise?	15 (1.4)	27 (1.6)
3	Have you ever fainted unrelated to exercise?	112 (10.7)	265 (16.1)
4	Do you experience dizzy turns during exercise?	67 (6.4)	162 (9.8)
5	Do you experience dizzy turns following exercise?	44 (4.2)	55 (3.3)
6	Do you experience dizzy turns unrelated to exercise?	123 (11.7)	217 (13.2)
7	Do you experience palpitations?	41 (3.9)	205 (12.5)
8	Do you experience chest pains, heaviness or tightness during exercise?	65 (6.2)	285 (17.3)
9	Do you experience chest pains, heaviness or tightness following exercise?	52 (4.9)	190 (11.5)
10	Do you experience chest pains, heaviness or tightness unrelated exercise?	68 (6.5)	285 (17.3)
11	Do you feel that you are more breathless or more easily tired than your team mates?	103 (9.8)	277 (16.8)
12	Is there a family history of heart disease?	313 (29.9)	586 (35.6)
13	Has there been unexplained death or deaths due to heart disease in young family members?	30 (2.9)	158 (9.6)

Data are means (%).

was defined as a biphasic P wave in V1 where the terminal portion was more negative than −0.1 mV and ≥0.04 seconds in duration. Left and right ventricular hypertrophy was determined by the Sokolow–Lyon voltage criteria. Left ventricular hypertrophy (LVH) was defined by the sum of the S wave in V1 and the R wave in either V5 or V6 being >3.5 mV. Right ventricular hypertrophy was defined by the sum of the R in V1 and the S in V6 being >1.05 mV. In addition, the presence of LVH was assessed by the Romhilt and Estes point-score system; with a score of ≥5 being used to define LVH. A Q wave was considered abnormal or pathological if >0.04 seconds in duration and/or if the depth of the Q wave was >5% of the height of the R wave. Based upon our previous experience of electrocardiographic and echocardiographic correlation studies in athletes, we did not consider isolated Sokolow–Lyon LVH patterns to be significant, as this is present in 65–80% of athletes.[1]

Statistical analysis

The qualitative closed questionnaire results were expressed in absolute number form and centile values per group. All other results are presented descriptively.

RESULTS

Junior athletes generally showed fewer symptoms than schoolchildren. In total, 29.9% of athletes reported a family history of heart disease, but only 2.9% reported an unexplained death or deaths due to heart disease in young family members. When the same two questions were asked of schoolchildren, the results were 35.6% and 9.6% respectively.

Of the participants screened, 4% required further examination because of an abnormal ECG and/or a positive questionnaire (table 3). The prevalence of junior athletes diagnosed with a cardiac disease was over twice (0.5%) that of schoolchildren (0.2%). Junior athletes also had the highest number of ECG abnormalities (2.3% vs. 0.9%), but tended to report the fewest personal symptoms and/or family history of SCD (1.8% vs. 2.9%).

None of the participants diagnosed with a disease associated with SCD were symptomatic. We identified three cases of electrical diseases associated with SCD, four cases of WPWS, one case of arrhymogenic right ventricular cardiomyopathy and one case of right ventricular outflow tract ventricular tachycardia.

All patients identified with a cardiac disorder that were deemed serious (table 4) underwent further investigation for the purposes of diagnostic clarity and risk stratification before therapeutic intervention.

DISCUSSION

Around 80% of non-traumatic sudden deaths in young athletes are caused by inherited or congenital structural and functional cardiovascular abnormalities, which provide a substrate for arrhythmias predisposing to SCD.[13] Previous demographic data on SCD in 134 deceased young athletes have shown that cardiovascular abnormalities were suspected in only 3% of examined athletes using standard history and physical examination, with <1% receiving a confirmed diagnosis.[20] The steady trickle of SCDs in young athletes has prompted calls for the implementation of systematic screening programmes. Current methods are largely pragmatic and based on personal history and physical examination.[11] In Italy, from 1979 to 1996, 33 735 young athletes have been systematically screened, with 1058 being prohibited from physical activity, of which 621 (58.7%) were associated with a cardiovascular cause.[6] In this cohort, the most common cardiovascular disorder warranting prohibition was rhythm and conduction abnormalities (38.3%). It is noteworthy that initial screening in Italy is based upon electrocardiography. Only 3016 (8.9%) young athletes required echocardiography due to suspicions of HCM, of whom 22 were subsequently diagnosed. Thus, <10% of the population underwent echocardiographic evaluation, saving a substantial expenditure.

Our study shows that personal symptoms are poor predictors of cardiovascular abnormalities. Furthermore, ominous symptoms, such as repeated syncope during exercise, all produced negative findings. Our ECG screening data identified nine children with potentially serious cardiovascular conditions, resulting in further investigations, appropriate risk stratification and potentially life-saving therapeutic intervention. Our programme involved the UK's leading experts in athlete's heart syndrome and inherited cardiovascular diseases, limiting our further investigations to 4% of the study population, compared with 10% in the Italian experience.[6] Certain personal symptoms, such as atypical chest pain without other major symptoms, were excluded from further investigation by our cardiologists on the day of screening, lowering rates of further investigation.

The 12-lead ECG is abnormal in >90% of patients with HCM, and HCM is reported as the commonest cause of SCD in young athletes.[1] Our study did not identify a single case of HCM. Most of the athletes we diagnosed with cardiovascular disease had ion-channel or electrical abnormalities that would not have been identified in a post-mortem examination. The 12-lead ECG will identify patients with WPWS, and the majority of patients with

Table 3 Results of screening in junior athletes and schoolchildren

	Junior athletes	Schoolchildren
Screened, n	1074	1646
Requiring further cardiological evaluation after the initial screening, n	45	62
Abnormal ECG, n	25	15
Serious symptoms and/or family history of SCD, n	20	47
Diagnosed with an SCD disease, n (%)	5 (0.5)	4 (0.2)
Prevalence	1 in 215	1 in 412

ECG, electrocardiogram; SCD, sudden cardiac death.

Table 4 Participants with a positive diagnosis of a disease associated with sudden cardiac death

Patient no	Gender	Abnormal ECG	Symptomatic	Family history of SCD	Diagnosis
1	Female	Yes	No	No	Long QT syndrome, type 1
2	Male	Yes	No	No	WPWS
3	Male	Yes	No	No	WPWS
4	Male	Yes	No	No	Long QT syndrome, type 1
5	Female	Yes	No	No	Right ventricular outflow tract ventricular tachycardia
6	Male	Yes	No	No	WPWS
7	Male	Yes	No	No	Arrhythmogenic right ventricular cardiomyopathy
8	Male	Yes	No	No	Long QT syndrome, type 1
9	Male	Yes	No	No	WPWS

WPWS, Wolff–Parkinson–White syndrome.

ion channelopothies, both of which cannot be detected with imaging tests.[1] Sorbo *et al*[16] examined 116 452 ECGs belonging to a cohort of 18-year-old boys. The investigation identified 173 cases of overt WPWS pattern (short PR interval, delta wave, anomalous configuration of QRS complex) with a calculated incidence of 1.48 per 1000. Interestingly, only 60 of the 173 (34.6%) patients were symptomatic (palpitations, near syncope and dizziness), suggesting 113 cases of false-negative diagnoses with the use of personal symptom and family history questionnaires alone. The results imply that without a positive personal symptom and family history questionnaire, 113 asymptomatic children would not have been diagnosed with WPWS if an ECG had not been carried out and if identification had relied on a questionnaire alone. The authors concede that the phenotypic features, namely, both ECG abnormalities and arrhythmic substrates, of most inherited heart muscle diseases posing a risk of sudden death in the young are age-dependent and occur during adolescence or young adulthood. Therefore, screening of young athletes and children might be expected to have low sensitivity for detection of cardiomyopathies and progressive cardiac conduction diseases that usually develop during the later period of life.

The role of symptom-based questions within the questionnaire is to identify children presenting with symptoms suggestive of cardiovascular disease, specifically syncope during exercise, seizures and prolonged periods of palpitations. Firoozi *et al*.[17] stated that unexplained syncope in a young athlete in the context of exercise should be considered to be an aborted sudden death until proved otherwise. This investigation found 20 and 47 positive cases of troublesome symptoms in junior athletes and schoolchildren, respectively, which required further examination. Within the schoolchildren group, there were more follow-up examinations due to positive personal symptom and family history questionnaires than to positive ECGs. We found that children presenting with symptoms or family history of cardiac disease were entirely healthy. The false-positive rate was higher for personal symptom and family history questionnaires than for ECG examination alone in schoolchildren.

Our study identified only 25 athletes with an abnormal ECG warranting further examination with a spectrum of methods including echocardiography. Such ECG alterations are most likely the consequence of athletic conditioning and represent another potential component of the athlete's heart syndrome.[15] However, further examination rates in the present study were low because of the extensive experience in the interpretation of athletes' ECGs by our cardiologists. It is imperative that only cardiologists with substantial experience of the athlete's heart and sudden cardiac death should perform the ECG examination, ultimately reducing the likelihood of recording false-positive or false-negative ECG findings.

We concede that the potential for false negatives using ECG alone without the use of echocardiography exists, even though the 12-lead ECG is abnormal in >90% of patients with HCM and in the majority of patients with ARVC.[1] Furthermore, congenital coronary artery anomalies include a variety of abnormal anatomical variations of the right and left coronaries, which could be missed in the absence of imaging techniques.[2] In favour of the technique, however, we have follow-up data over years with no deaths, indicating a robust screening approach.

CONCLUSION

Although the exact number of young SCD cases is unknown, the incidence is low. Our study confirms that personal symptoms and family history questionnaires alone are inadequate in the identification of children with diseases associated with SCD, and supports the recommendations of a number of bodies including the International Olympic Committee, European Society of Cardiology, and the Fédération Internationale de Football Association (FIFA).

In conclusion, resting 12-lead ECG is essential when screening for diseases that have the potential to cause sudden death in the young.

What is already known on this topic

- The death of a young athletic individual is a tragic and highly publicised event that causes great debate within the lay community, and can largely be attributed to a number of inherited or congenital cardiac pathologies.
- The purpose of pre-participation screening is to provide medical clearance for participation in sport through routine systematic evaluations intended to identify pre-existing cardiovascular abnormalities and thereby reduce the potential for adverse events and loss of life.
- The methodological approaches to cardiovascular screening in young athletic children have been debated widely by sports medicine practitioners and cardiologists for a variety of reasons: cost-effectiveness, rates of false positives and negatives, and ethical and legal issues.

What this study adds

- This paper provides a best practice model for pre-participation cardiac screening in young athletic children.
- Personal symptoms and family history questionnaires alone are inadequate in the identification of children with diseases associated with sudden cardiac death.
- The inclusion of resting 12-lead ECG is essential when screening for diseases that have the potential to cause sudden death in the young.

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