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RESEARCH

Cardiovascular evaluation, including resting and exercise electrocardiography, before participation in competitive sports: cross sectional study

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ABSTRACT

Objective To evaluate the clinical usefulness of complete preparticipation cardiovascular screening in a large cohort of sports participants.

Design Cross sectional study of data over a five year period.

Setting Institute of Sports Medicine in Florence, Italy.

Participants 30 065 (23 570 men) people seeking to obtain clinical eligibility for competitive sports.

Main outcome measures Results of resting and exercise 12 lead electrocardiography.

Results Resting 12 lead ECG patterns showed abnormalities in 1812 (6%) participants, with the most common abnormalities (>80%) concerning innocent ECG changes. Exercise ECG showed an abnormal pattern in 1459 (4.9%) participants. Exercise ECG showed cardiac anomalies in 1227 athletes with normal findings on resting ECG. At the end of screening, 196 (0.6%) participants were considered ineligible for competitive sports. Among the 159 participants who were disqualified at the end of the screening for cardiac reasons, a consistent proportion (n=126, 79.2%) had shown innocent or negative findings on resting 12 lead ECG but clear pathological alterations during the exercise test. After adjustment for possible confounders, logistic regression analysis showed that age >30 years was significantly associated with an increased risk of being disqualified for cardiac findings during exercise testing.

Conclusions Among people seeking to take part in competitive sports, exercise ECG can identify those with cardiac abnormalities. Follow-up studies would show if disqualification of such people would reduce the incidence of CV events among athletes.

INTRODUCTION

Preparticipation screening is the systematic practice of evaluating sports participants before competition to detect cardiovascular abnormalities and thus prevent sudden death or progression of disease.[1,2] In Italy, such screening constitutes an established medical programme that has been implemented for more than 25 years.[3] Over the past few decades, clinicians and experts have debated its clinical usefulness in identifying those at high risk.[4-6] Corrado et al recently showed a significant decrease in the incidence of sudden death in young Italian athletes who had undergonesuch screening.[7] The European Society of Cardiology and the International Olympic Committee, taking note of Italy's 25 years of experience, underlined the need for medical examination for young competitive athletes before they take part in organised sports programmes,[1,8] though the recently updated recommendations of the American Heart Association do not support this medical perspective.[2]

We analysed data from the Institute of Sports Medicine in Florence, Italy, on cardiovascular evaluation, including resting and exercise electrocardiography, in a large unselected population of sports participants.

METHODS

Study population

The study population included 30 065 participants who were referred, during a five year period (2002-6), to the Institute of Sports Medicine to obtain eligibility to take part in competitive sports. All participants were examined with first line investigations, as required under Italian law.[9] Since 1982, people participating in all officially sanctioned sports must undergo medical screening that includes personal and family history, physical examination, and resting and exercise 12 lead electrocardiography (ECG).[9] Additional tests are requested only for those with positive results in the initial evaluation and are performed by major hospitals or centres other than the institute. Criteria for positive family and personal history, physical examination, and ECGs are those established by Italian protocol and are reported elsewhere.[7,9,10] All participants gave written informed consent.

Statistical analysis

Statistical analysis was performed with SPSS (Chicago, IL, USA) software for Windows (version 13.0). Continuous variables were expressed as means and standard deviations (SD) for parametric data or median and range for non-parametric data. We used the non-parametric Mann-Whitney test for comparison between single groups, the Kruskal-Wallis test for comparison among different groups, and χ^2 to test comparisons between proportions. After adjustment for possible confounders (sex, age group (<30, 30-50, >50), body mass index (BMI), family history, systolic blood pressure, diastolic blood pressure, smoking habits (yes or no), heart rate, type of sport practised), we carried out logistic regression analysis to evaluate possible predictors of disqualification among athletes with a normal resting ECG pattern. P value <0.05 indicated significance.

RESULTS

Characteristics of the study population

The study population included 30 065 participants, with significantly (P<0.001) more men than women (23 570 (78.4%) *v* 6495 (21.6%)). The mean age was 30.7 (SD 14), with a range of 5-92; 33 were aged over 80. Nearly 40% of the total study population were aged over 30, and 98% were white. Men were significantly older than women (28.4 *v* 24.6; P<0.001) and included a significantly higher proportion of smokers (13.2% *v* 10.3%; P<0.001). More than half of the participants were reported to have a sedentary job (56.2%), with no significant difference between men and women. Most people spent an average of four to six hours a week doing sports activities (50.9%), whereas the rest were reported to spend less than four or more than six hours a week (20.7% and 28.4%, respectively) taking part in sports.

Participants took part in over 30 different sporting disciplines, the main ones being football and volleyball (31.3% and 17.7%, respectively). Other leading sports were cycling (6.7%), athletics (5.9%), and basketball (5.8%) among men and swimming (6.5%), athletics (6%), and gymnastics (4.2%) among women.

Personal and family history indicated cardiac abnormalities in less than 0.5%, whereas physical examination reported pathological findings in about 3%.

Table 1 | Results of 12 lead resting and exercise electrocardiography in people screened before taking part in competitive sports. Figures are number (percentage) of participants

	All (n=30 065)	Men (n=23 570)	Women (n=6495)	P value (men *v* women)
Resting electrocardiography				
Normal	28 253 (94)	22 000 (93.3)	6253 (96.3)	<0.001
PVBs	120 (0.4)	95 (0.4)	25 (0.4)	0.9
PSVBs	30 (0.1)	24 (0.1)	6 (0.09)	0.9
PEP	27 (0.09)	21 (0.09)	6 (0.09)	0.7
First degree AVB	30 (0.1)	24 (0.1)	6 (0.09)	0.9
Second degree AVB	3 (0.01)	3 (0.01)	—	—
LABB	6 (0.02)	5 (0.02)	1 (0.01)	0.8
RBBB	331 (1.1)	306 (1.3)	25 (0.4)	<0.001
Sinus bradycardia	872 (2.9)	754 (3.2)	118 (1.8)	<0.001
Incomplete RBBB	210 (0.7)	189 (0.8)	21 (0.3)	<0.001
ERP	21 (0.07)	19 (0.08)	2 (0.03)	0.2
ST-T alterations	150 (0.5)	118 (0.5)	32 (0.5)	0.9
Wandering PM	3 (0.01)	3 (0.01)	—	—
Junctional rhythm	3 (0.01)	3 (0.01)	—	—
AF	6 (0.02)	6 (0.03)	—	—
Exercise electrocardiography				
Normal	28 606 (95.1)	22 632 (96)	5974 (92)	<0.001
Isolated PVBs	815 (2.7)	524 (2.2)	291 (4.5)	<0.001
Isolated PSVBs	467 (1.6)	319 (1.4)	148 (2.3)	<0.001
Paired PVBs	58 (0.2)	33 (0.1)	25 (0.4)	<0.001
Paired PSVBs	31 (0.1)	14 (0.06)	17 (0.3)	<0.001
NSTV	3 (0.01)	2 (0.009)	1 (0.01)	0.6
SVT	3 (0.01)	2 (0.009)	1 (0.01)	0.6
ST-T alterations	54 (0.2)	26 (0.1)	28 (0.4)	<0.001
Second degree AVB	8 (0.03)	7 (0.03)	1 (0.01)	0.5
RBBB	20 (0.07)	11 (0.05)	9 (0.1)	0.01

PVBs=premature ventricular beats; PSVBs=premature supraventricular beats; PEP=pre-excitation pattern; AVB=atrioventricular block; LABB=left anterior bundle block; RBBB=right bundle branch block; ERP=early repolarisation pattern; PM=pacemaker; AF=atrial fibrillation; NSTV=non-sustained ventricular tachycardia; SVT=sustained ventricular tachycardia.

Resting 12 lead electrocardiography

Abnormalities on resting ECG were present in 1812 (6%) participants, 1570 (6.7%) men and 242 (3.7%) women (P<0.001) (table 1). The most common abnormalities were sinus bradycardia (2.9%) and complete (1.1%) or incomplete (0.7%) right bundle branch blocks, which, together with the type I atrioventricular block and early polarisation pattern, can be considered as innocent modifications that occur in the "athlete's heart." These abnormalities accounted for over 80% of the total anomalies (n=1464). A distinctly abnormal pattern was found in the remaining participants (348; 1.2%), the most common being ST-T segment alterations and premature ventricular and supraventricular beats. There was a higher prevalence of innocent ECG changes in men than in women, with the exception of type I atrioventricular block.

With regard to age, participants with reported ECG abnormalities were significantly older than those with a normal ECG pattern (31.1 (SD 13.8) *v* 29.1 (SD 13.1), P<0.001). Almost half of the population with ECG irregularities comprised participants aged 30-50 (46.9%), with the remaining portion mostly being those aged under 30 (33.6%).

Exercise 21 lead electrocardiography

All participants underwent exercise ECG (table 1), and abnormalities were found in 1459 (4.9%), with a higher prevalence in women than men (521 (8%) *v* 938 (3.9%)). Those with abnormalities were significantly older than those with normal patterns (30.9 (SD 12.1) *v* 24.9 (SD 9.9), P<0.001), and an equal proportion (48.9%) were aged over 30. The most prevalent anomalies were premature ventricular and supraventricular beats, accounting for over 65% of the total abnormalities, with a significantly higher prevalence among women than men (P<0.001). The remaining abnormalities comprised non-sustained and sustained ventricular tachycardia, ST-T segment alterations, and cardiac

Table 2 | Causes of disqualification from competitive sports at the end of screening

	No (%)	Mean age (SD; range)
Valve diseases	47 (23.9)	39.9 (14.3; 18-64)
Arrhythmias	36 (18.4)	35.4 (13.4; 12-71)
Coronary artery disease	17 (8.7)	40.5 (13.9; 18-83)
Conduction disorders	13 (6.6)	33.7 (19.6; 17-69)
Hypertension	37 (18.9)	42.8 (11.3; 20-73)
Cardiomyopathies	9 (4.6)	28.4 (13.8; 8-63)
Other*	37 (18.9)	38.9 (16.4; 15-72)

*Malignancies, hip and knee prosthesis, venous thromboembolic disease, eye diseases, hearing loss, seizures, mental disorders.

conduction disorders. Notably, only 232 (12.8%) participants with abnormalities on resting ECG also showed these abnormalities on exercise ECG, but exercise ECG showed cardiac anomalies in 1227 participants (939 men; 288 women; mean age 30.7 (SD 11.9)) in whom resting ECG had shown a normal pattern. In particular, the most prevalent cardiac abnormalities found on stress testing comprised findings suggestive of coronary heart disease and arrhythmias.

Eligibility and screening

After screening, 196 (0.6%) people were considered ineligible to take part in competitive sports (182 (0.7%) men and 14 (0.2%) women; mean age 37 (SD 12.3)). In total 159 (81.6%) athletes were disqualified because of cardiac abnormalities, and 37 were disqualified for other reasons (table 2).

By analysing disqualifications according to abnormalities found at resting and exercise ECG, we found that, among the 159 participants disqualified because of cardiac abnormalities, personal history or physical examination, or both, had suggested problems in only six (3.7%) and a large proportion (126, 79.2%) had a normal pattern on resting ECG. Conversely, almost all the disqualified participants showed some cardiac abnormalities during the exercise ECG. Indeed, in 56 participants with a normal resting ECG, exercise testing showed some potentially fatal cardiac disorders such as arrhythmias and coronary heart disease that resulted in disqualification from competition.

Finally, we performed a logistic regression analysis to investigate possible predictors of disqualification among the group of participants with a normal resting ECG. After adjustment for possible confounders we found that the risk of being disqualified increased significantly with age. Participants aged over 30 had a significantly increased risk of showing cardiac abnormalities on exercise ECG, thus resulting in disqualification from competition (table 3).

DISCUSSION

Findings from this cross sectional study, although only preliminary and not supported by follow-up analyses, support the inclusion of resting and exercise ECGs to detect cardiac abnormalities such as ventricular and supraventricular arrhythmias and coronary heart disease among people taking part in competitive sports, especially those who are middle aged and older. A consistent proportion of people disqualified for cardiac disorders showed innocent or negative findings on resting 12 lead ECG but clear pathological alterations on exercise ECG.

Over the past few decades, there has been increasing interest in the role of cardiovascular screening to identify potentially fatal cardiac disorders among athletes before they take part in competitive sports.[1-7 11 12] , Routine use, however, is far from accepted and still raises several important unresolved questions of ethical and practical importance. First of all, the clinical importance of changes in the athlete's heart on ECG is not fully established. In our analysis, as in previous studies,[12] the most prevalent abnormalities on resting ECG were typical of an athlete's heart. In this scenario, the implementation of ECG screening would probably result in a large number of borderline and false positive results, leading to additional tests to resolve the clinical ambiguity, worry and emotional stress for the participants, and considerable financial costs. On the other hand, some participants with innocent abnormalities showed a clear pathological pattern on exercise ECG, resulting in disqualification from competition. This is in line with results of Pelliccia et al, who recently showed that an abnormal repolarisation pattern, generally regarded as an innocent consequence of athletic conditioning, might represent the initial expression of underlying disease, thus meriting further clinical consideration.[13]

The cost of such a programme is also important. In Italy it costs an estimated €30 (£24, $47) per participant. The implementation of such a programme would definitely result in additional costs for the National Health Service and for the population as a whole. Nevertheless, decreasing the risk of sudden death among competitors is extremely important as it has a considerable impact on both lay and medical communities because of the broadly held view that athletes constitute the healthiest people in society.

Table 3 | Predictors of disqualification among athletes with normal findings on resting ECG

Variable	Odds ratio (95% CI)	P value
Sex (men *v* women)	0.61 (0.20 to 1.85)	0.4
Age 30-50	2.38 (1.07 to 5.92)	0.02
Age >50	4.49 (1.68 to 11.05)	0.003
BMI	1.03 (0.93 to 1.13)	0.6
Family history	1.06 (0.87 to 2.34)	0.8
Diastolic blood pressure (mm Hg)	1.01 (0.97 to 1.05)	0.7
Systolic blood pressure (mm Hg)	0.99 (0.97 to 1.02)	0.6
Type of sport practised	0.94 (0.83 to 1.06)	0.3
Heart rate (bpm)	0.99 (0.96 to 1.01)	0.3
Smoking habit	0.59 (0.28 to 1.29)	0.2

BMI=body mass index; bpm=beats per minute.

WHAT IS ALREADY KNOWN ON THIS TOPIC

Cardiovascular events during sports are tragic occurrences that attract public and media attention

Evaluation of competitive athletes before participation might reduce the risk of cardiovascular death or events during competition

WHAT THIS STUDY ADDS

The inclusion of resting and exercise electrocardiography to the standard medical evaluation of sports participants helps to identify those at high risk

Exercise electrocardiography can show clear pathological findings in participants with negative or innocent findings at physical examination and resting electrocardiography

Limitations

Because of the observational design of this study, we were unable to show if these clinical evaluations are effective in reducing the risk of mortality or incidence of cardiac accidents in sports participants. Only a prospective analysis of these data will help us to test this hypothesis. None the less, some previous studies have reported on the clinical efficacy of such cardiovascular screening on reducing sudden death among athletes.[7 11 13] Moreover, results of second line investigations in participants with a positive screening result are not available, making it difficult to interpret the real diagnostic power of baseline and exercise ECGs, as well as the important matter of false positive results.

Our study, however, provides relevant information especially for middle aged and elderly people participating in sports, and shows a significant prevalence of some potentially fatal cardiac diseases such as coronary heart disease and hypertension.

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