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Prevention of Sudden Cardiac Death in Non-Competitive Athletes: ECG Screening by Telecardiology Is Useful and Cost-Effective

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Abstract: *Background:* Sudden cardiac death (SCD) is the leading cause of mortality in athletes during sport. There are several hereditary, structural, or electrical heart diseases associated with SCD, most of them can be identified or suggested by abnormalities on a resting 12-lead electrocardiogram (ECG). *Objective:* To evaluate usefulness and cost-effectiveness of ECG screening, using a telecardiology system, in order to detect cardiovascular diseases that might cause SCD in a cohort of non-competitive athletes (NCA). *Methods:* ECGs received at the Telecardiology Center (Telemedico Srl, Genoa) for non-competitive sports, in a 3-month period were analyzed. According to the age we distinguished: NCA < 35 years (group A) and NCA > 35 years (group B). *Results:* A total of 6345 NCA (4078 males, 64.2%) were evaluated between the ages of 5 and 50 years (mean ± SD: 28.4 ± 12.6). Group A (age < 35 years) consisted of 3453 (54.4%) NCA and group B (age > 35 years) of 2892 (45.6%) respectively. An ECG pattern at risk of SCD has been identified in 295 (4.6%) subjects. Prevalence of ECG abnormalities was higher for group B (154/2892; 5.3%) than group A (141/3453; 4.1%); the difference was significant (p= 0.016). The average cost per ECG was € 12. The cost of ECG screening to identify a risk situation of SCD was € 258. *Conclusion:* ECG screening through telecardiology of NCA results to be feasible, useful and cost-effective.

Keywords: Athletes, Telecardiology, ECG Screening, Sudden Cardiac Death

1. Introduction

Sudden cardiac death (SCD) is the leading cause of mortality in athletes during sport and it's known that medical evaluation of athletic populations before competition offers the potential to identify asymptomatic athletes with potentially lethal cardiovascular abnormalities and to prevent SCD through disqualification from competitive sports [1]. There are several hereditary, structural, or electrical heart diseases associated with SCD, most of them can be identified or suggested by abnormalities on a resting 12-lead electrocardiogram (ECG) [2].

At present, the role of ECG screening in competitive athletes is still under debate with some major organizations supporting ECG use, and others recommending against widespread ECG-inclusive screening [3-6].

Since 1982, in Italy pre-participation screening is governed by decree of the Italian Ministry of Health, which requires physician-led screening with history, physical, and ECG for competitive athletes [7]. Furthermore, since 2012 also the practice of a non-competitive sport requires, in Italy, the execution of at least an ECG in order to identify situations at risk of SCD.

Telemedicine allows health care professionals to evaluate,

diagnose and treat patients at a distance using telecommunications technology. Among the wide range of medical specialties in which telemedicine has been successfully applied, cardiology can be considered as one of the most important fields of application. Through the transmission of clinical data and the electrocardiogram, telecardiology allows access to a real-time assessment (teleconsultation) without any need to travel for both patient and cardiologist [8, 9]. Furthermore most cost-effectiveness studies demonstrate that telecardiology can reduce costs for the National Health Service [8].

Recently, telecardiology has been used as a preparticipation screening method for the evaluation of sport subjects [10]. Recent years have witnessed a growing number of people practising sports both at competitive and non. competitive level. This trend could lead to a progressive rise in the incidence and prevalence of sport-related SCD, especially for master non-competitive athletes (NCA).

The aim of this study was to evaluate usefulness and cost-effectiveness of ECG screening, through a telecardiology system, in order to detect cardiovascular diseases that might cause SCD in a cohort of NCA.

2. Methods

Data derived from subjects aged between 5 and 50 years referred for ECG analysis as a pre-participation screening for non-competitive sports at the ‘‘Telemedico’’ Telecardiology Centre (Genoa, Italy) between 1 September and 30 November, 2022 were digitally stored and analyzed. ECGs were recorded and sent by a network of ‘spoke’ centers located all over Italy; a ‘hub’ center, located in Genoa, received and reported back on ECGs. For all subjects, besides registry data, a detailed clinical and pharmacological history was obtained by the referring center through an electronic form. Only good-quality, artifact-free recordings of subjects with complete clinical data and without known congenital or acquired heart disease, not receiving long-term therapy or medical treatment in the 48-hours preceding the exam, were used in this study.

The study was performed in accordance with the Declaration of Helsinki [11] and approved by an ethical committee.

2.1. ECG Recording and Measurements

TeleCardioCalm telecardiology system was used. It is a multi-vendor system compatible with various digital acquisition units of the electrocardiographic signal that allows secure transmission of the acquired exam for viewing and reporting by the cardiologist in a certified web-based platform. The devices used for the acquisition of the ECGs all allow the recording of a simultaneous 12-lead ECG signal of high diagnostic quality:

1) Spaulding 2100iQ by Spaulding Clinical Research, LLC, Sampling Rate: 500 s/sec/channel, Frequency Response: 0.05 to 250 Hz, Filtering: High Pass Filter to remove baseline wander, Low Pass Filter to remove high frequency noise.
2) ECGExpert by Custom Software & Electronics, SL, Sampling rate: 500 s/sec/channel, Frequency response: From -3dB@ 0.02 to 150 Hz, Filter: High Pass Filter to remove baseline wander, 40 Hz Low Pass filter to remove high frequency noise.

For remote ECG viewing and reporting, the system integrates the web-based software WebCor, a certified medical device that automatically measures ECG time intervals and allows the doctor to analyze and measure the traces by creating a digitally signed report with a strong signature.

2.2. ECG Interpretation

Only ECG anomalies as suggested by International Recommendations for Electrographic Interpretation in Athletes were considered situation at risk of SCD [2].

We considered as “T wave inversion” pattern all ECGs presenting T wave inversion with or without ST segment depression outside the normal juvenile pattern (inversion in leads V1–V3 under the age of 16 years).

2.3. Data Collection

The following parameters were collected: age, sex, ethnicity, and sports category according to the Mitchell criteria [12]. In addition, symptoms onset in the last 48 hours such as chest pain, palpitations and dyspnea, and suggesting for underlying heart disease were considered.

To test the hypothesis that the prevalence of ECG abnormalities is higher in master athletes we divided our population according to age: athletes < 35 years (group A) and athletes > 35 years (group B).

2.4. Statistical Analysis

Categorical data are expressed as counts (%) while continuous data are expressed as mean with standard deviation (SD).

Student’s t test was used to test the prevalence of ECG abnormalities between the two groups, using Microsoft Excel tool. A $p < 0.05$ was considered statistically significant.

Costs were calculated in euros. The cost of each ECG varied from 6 to 15 euros, based on the commercial agreement drawn up between the spoke center and the hub center.

3. Results

We included 6345 non- competive athletes with a mean age of 28.4± 12.6 (SD) years (range 5 to 50). Approximately, two-thirds of the cohort were males (4078; 64.2%) and most athletes were of Caucasian ethnicity (4972; 78.4%). Football was the most common single sport represented (1427; 22.5%). Group A (age < 35 years) consisted of 3453 (54.4%) NCA and group B (age > 35 years) of 2892 (45.6%) respectively.

Of the 6345 NCA, 295 (4.6%) demonstrated abnormal findings on standard 12-lead ECG according to the International Recommendations for Electrocardiographic

Interpretation in Athletes. Prevalence of ECG abnormalities was higher for group B (154/2892; 5.3%) than group A (141/3453; 4.1%); the difference was significant (p= 0.016).

Table 1 shows the prevalence of the different ECG abnormal findings that might cause SCD.

Table 1. *ECG patterns at risk of SCD.*

ECG abnormality	Patients (n)	Percentage (%)
T wave inversion	59	20.0
QRS duration >140 msec	16	5.4
Epsilon wave	2	0.7
Ventricular pre-excitation	6	2.1
Brugada Type 1 pattern	1	0.3
Prolonged QT interval (≥ 480 msec)	2	0.7
Mobitz Type II 2° atrioventricular block	4	1.4
Atrial tachyarrhythmias (Supraventricular tachycardia, atrial fibrillation, atrial flutter)	50	16.9
≥ 2 PVCs per 10 s tracing	108	36.6
Ventricular arrhythmias (Couplets, triplets, and non-sustained ventricular tachycardia)	47	15.9
Total	295	100.0

3.1. ECG Abnormalities

Ventricular arrhythmias. In this subgroup we have to distinguish 2 different patterns: single premature ventricular contractions (PVCs) occurring ≥ 2 times in the 10 seconds of ECG trace recording and detected in 108/295 (36.6%) subjects, and arrhythmic patterns ranging from PVCs couplets to not sustained ventricular tachycardia demonstrated in 47/295 (15.9%) subjects.

Atrial tachyarrhythmias. These arrhythmias were recorded in 50/295 (16.9%) NCA; the diagnosis was supraventricular tachycardia lasting > 10 seconds in 2 cases (Figure 1), supraventricular tachycardia lasting < 10 seconds in 14 cases, and atrial fibrillation or flutter in 30 and 4 subjects, respectively.

T wave inversion. This abnormal finding was detected in 59/295 (20%) athletes; an association with ST-segment depression was found in 27 subjects and with right bundle branch block in 6. Moreover, an ECG pattern characterized by the inversion of giant T wave and suspicious for hypertrophic cardiomyopathy was detected in 2 subjects.

QRS duration >140 msec. A left bundle branch block was discovered in 16/295 (5.4%) subjects.

Ventricular pre-excitation. A Wolff-Parkinson-White ECG pattern was detected in 6/295 (2.1%) NCA with ECG abnormalities.

ECG changes suspected for *channelopathies* (i.e, Brugada Syndrome and Long QT Syndrome) and *Mobitz Type II 2° atrioventricular block* resulted very rare in our population (about 1% of ECG abnormalities).

A clear *epsilon wave* associated with a right bundle branch block in 2/295 (0.7%) subjects.

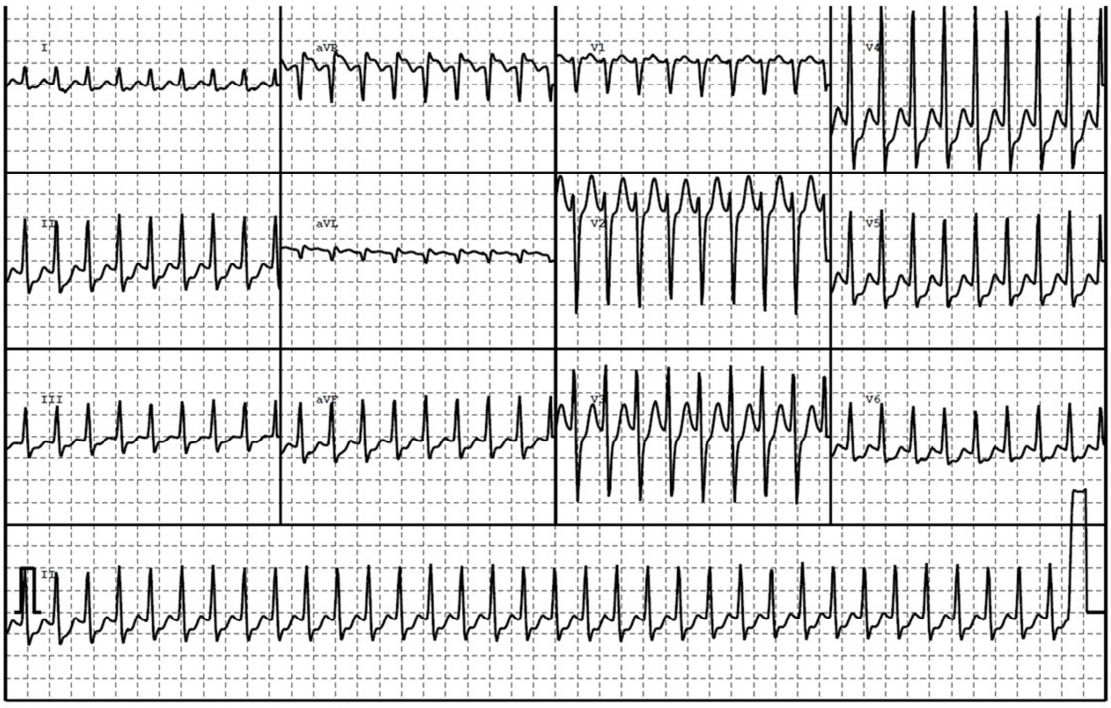

Figure 1. *The ECG of a 36-year-old female shows an atrio-ventricular node reentrant tachycardia with symptoms (palpitations) starting 5 minutes before the*

pre-participation ECG screening.

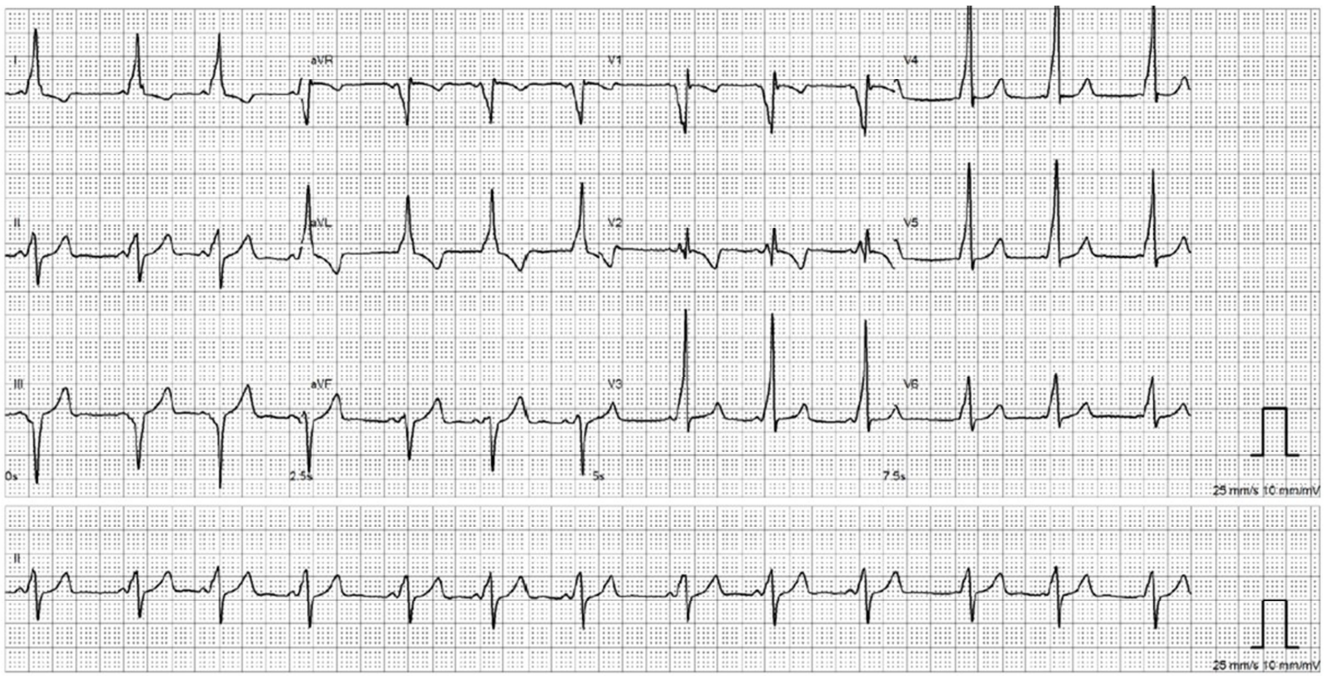

Figure 2. *ECG of asymptomatic 6-year old male shows a Wolff-Parkinson-White Pattern with a right postero-septal accessory pathway.*

3.2. Symptoms

Symptoms have been reported in 497 (8%) subjects and concerned palpitations in 315 (63.4%) subjects, chest pain in 124 (24.9%), and dyspnea in 57 (11.7%) respectively. In the subgroup with palpitations only 72 (22.9%) presented ECG changes such as ventricular (10.4%) or supraventricular (12.5%) arrhythmias. Among the 124 athletes with chest pain we detected T wave inversion in 18 (14.5%) and a left bundle branch block in 4 (3.2%) subjects. Finally, the 57 subjects symptomatic for dyspnea had left bundle branch block in 6 (10.5%) cases and atrial fibrillation in 7 (12.3%).

3.3. Cost-Analysis

The average cost per ECG was 12 euros. Costs for basic ECG screening of the 6345 NCA amounted to 76,140 euros, 41,436 euros for group A and 34,704 for group B. Consequently, the cost of the ECG screening in identifying a situation at risk of SCD was 258 Euros, 294 euros in group A and 225 in group B.

4. Discussion

The risk of sports related SCD increases exponentially among individuals >35 years and is almost exclusively related to the development and progression of atherosclerotic coronary artery disease [13]. The growing number of middle-aged/senior subjects engaged in leisure-time sports activity, outside the competitive sports community, makes the preparticipation screening of these NCA an emerging task, with specific problems in terms of feasibility, logistics, and costs.

ECG screening for NCA is a controversial topic, and guidelines for ECG screening vary depending on the country and professional organization. However, some general recommendations can be made:

The American Heart Association recommends a cardiovascular evaluation for all individuals prior to starting a new exercise program, regardless of whether they are competitive athletes or not. The evaluation typically includes a medical history, physical examination, and possibly additional testing such as an ECG or echocardiogram [5].

The European Society of Cardiology recommends a 12-lead ECG for all competitive athletes, but does not recommend routine ECG screening for NCA [14].

In Italy ECG screening is mandatory for all individuals engaged in regular sports activity, including NCA [15, 16].

This observational prospective study was designed to determine the diagnostic yield and financial implications of ECG screening among non-competitive Italian athletes. The spectrum of cardiovascular diseases identified in this cohort included congenital or acquired heart diseases, genetic channelopathies, life threatening arrhythmias and atherosclerotic coronary artery disease.

Main findings of this study can be summarised as follows:

1) The rate of abnormal ECG findings strictly based upon the International Recommendations for Electrocardiographic Interpretation in Athletes requiring further investigations was high amounting to 4.6%. This is probably due to the high percentage of athletes with ≥ 2 PVCs in the 10 seconds of ECG recording (108/295; 36.6%). However, it should be noted that single monomorphic extrasystoles originating from the right ventricular outflow tract are a frequent ECG finding and have been shown not to be a trigger

for SCD [17].

2) The prevalence of supraventricular arrhythmias and T-wave inversion, with or without ST-segment depression, was particularly relevant. Since these ECG anomalies generally affect adulthood, we can explain the phenomenon with the high percentage of subjects (45.6%) aged ≥ 35 years, in our population. On this basis our data do not differ from other trials investigating master athletes [18, 19].
3) ECG screening has proved to be an accurate method to detected ECG abnormalities either in symptomathic subject or in asymptomathic athletes with underlying heart disease (i.e., Brugada Syndrome, Long QT Syndrome, Wolff-Parkinson-White Syndrome). In contrast, 390 (78.5%) of 497 symptomatic athletes had a normal ECG and were excluded from second level investigations.
4) Telecardiology has proved to be the best way to apply ECG screening in any context, allowing for the evaluation of large cohorts of subjects in a short time, in our study more than 6000 athletes in just 3 months.

Despite the lack of randomized control trials, previous studies suggested that telecardiology is both cost-utility and cost-effectiveness in different application settings. In our study, the average ECG cost was significantly lower than reported in the literature [20, 21]. Therefore, ECG screening of NCA using a telecardiology system is recommended.

Study limitation. This is an exclusively electrocardiographic study; no data are available on clinical follow-up and further instrumental or genetic examinations. Although an 'abnormal' ECG is not always by itself a disease, at the same time, several disease conditions may be undetected by an ECG.

Cost analysis takes into account only the ECG price that the "Spoke" center pays to the "Hub" center. It was not possible to exactly quantify the price that the every athlete pays to the "Spoke" center (generally variable between 20 and 25 euros).

5. Conclusion

Proponents of ECG screening for NCA argue that it can identify individuals with underlying cardiac conditions that may put them at risk for SCD during exercise. However, opponents argue that routine ECG screening can lead to false positives, unnecessary further testing, and psychological distress for individuals who are misdiagnosed. Ultimately, the decision to perform ECG screening for NCA should be made on an individual basis, after careful consideration of the potential benefits and risks.

Our study results suggest that the Italian prepartecipation programme by yearly ECG screening of NCA may allow earlier identification of underlying cardiac disordes at risk of SCD during sports. ECG screening using telecardiology results to be feasible, useful and cost-effective.

Abbreviations

ECG: Electrocardiogram
PVCs: Premature Ventricular Contractions
SD: Standard Deviation
SCD: Sudden Cardiac Death
NCA: Non-Competitive Athletes

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