VALIDITY OF ELECTROCARDIOGRAPHIC VOLTAGE CRITERIA: HOW USEFUL ARE THEY IN ATHLETES?

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ABSTRACT

Electrocardiographic (ECG) criteria for left ventricular (LV) hypertrophy have been almost exclusively elaborated and calibrated in general population. Because several differences in ECG characteristics have been found in athletes, the applicability of these criteria to athletes individuals remains to be demonstrated. We therefore investigated the performance of classic ECG criteria (Sokolow-Lyon voltage criterion) for detection of LV hypertrophy in professional athletes. We compared ECG patterns with cardiac morphology (as assessed by echocardiography) in 90 athletes (aged 23.4±4.3 years). we found that, the value of Sokolow-Lyon voltage criterion in athletes ranged from 18 to 53 mm (mean, 34.7+8 mm), and about 56% of them had Left ventricular hypertrophy according to this criterion. The sensitivity of ECG to detect correctly the presence of ventricular hypertrophy in athletes is low (63.6%) which means that the ECG missed 36.4% of cases of left ventricular hypertrophy. On the other hand, the ECG ability to exclude ventricular hypertrophy among athletes without such condition (specificity) was very low (50.9%). So that, caution should be taken when using ECG voltage criteria for LV hypertrophy detection in athletes because they exhibit only limited accuracy (generally due to poor sensitivity and specificity).

INTRODUCTION

Apparently fit and healthy young athletes occasionally drop dead. In most cases postmortem examination reveals previously unexpected cardiac disease such as hypertrophic cardiomyopathy, but in a significant minority of such individuals no apparent cause is found, although physiological LV hypertrophy is often noted. It is unclear whether this physiological LV hypertrophy is in some way implicated in the sudden deaths of some young athletes.[1,2,3] The term physiological LV hypertrophy has been generally applied to the increase in LV mass that occurs in response to repetitive physical exertion.[4] The distinction between physiological and pathological hypertrophy is critical because the decision in each case is very different and may deprive a professional athletes from continuing his or her carrier. The echocardiographic examination has contributed significantly to such distinctions but it is not always available and requires experience to interpretate its results. ECG may provide a simple and an alternative method to detect and identify cardiac changes in athletes.[5,6] In most previous studies, 12-lead ECG shows a board range of abnormal patterns in trained athletes, particularly increased QRS voltages, which are suggestive of LV hypertrophy, and repolarization abnormalities. These alterations have been attributed to the physiological cardiac adaptations that occur as a consequence of systemic physical training. [7,8] The validity of ECG changes is, however, questionable in athletes. In this paper we shall examine the validity of the electrocardiography as a diagnostic method of cardiac changes in athletes.

METHODOLOGY

A comparative study was conducted on 174 individuals (90 professional athletes and 84 healthy sedentary medical students). In addition to socio-demographic characteristics and blood pressure measurement, each participant was subjected to a thorough clinical examination to exclude any cardiac pathology. All participants were examined by non-invasive techniques: echocardiography and electrocardiography. Weight and height were also measured to calculate the body surface area. standard 12 lead resting electrocardiogram was recorded on an (SCHILLER-AT 2 PLUS) six channel electrocardiograph at a paper speed of 25 mm/s. Vertically, the ECG graph measures the amplitude of a given wave or deflection (1mV =

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10 mm with standard calibration; the voltage criterion for hypertrophy mentioned below are given in millimeters).

The following criterion was examined to test the presence of left ventricular hypertrophy[1,2,8]:

Sokolow-Lyon criterion: SV1 + RV5 or 6 ≥ 35 mm.

The 174 selected individuals underwent a complete echocardiographic investigation performed by one trained investigator with (Kritze technique Voltion R 530 D Software version 4). Left ventricular mass (LVM) was calculated from left ventricular interventricular septum (IVS), posterior wall thickness (PWT), and cavity dimension (LVDD) using anatomically validated formula proposed by Devereux [9-11]:

LVM = 0.8 [1.04 (IVS + PWT) 3 - (LVDD) 3] + 0.6 gm

Left ventricular mass index (LVMI) was calculated by dividing mass by body surface area (BSA). Left ventricular hypertrophy was considered present when the LV mass index was > 130 g/m2.[9]

The accuracy of the ECG is validated against the results of the echocardiography. The sensitivity and the specificity of the ECG to correctly recognize or exclude the presence of ventricular hypertrophy were calculated as follow:[12]

$$\text{Sensitivity} = \frac{\text{Number of persons with ventricular hypertrophy according to the results of ECG and ECHO}}{\text{Number of persons with ventricular hypertrophy according to the results ECHO}} \times 100$$

$$\text{Sensitivity} = \frac{\text{Number of persons without ventricular hypertrophy according to the results of ECG and ECHO}}{\text{Number of persons without ventricular hypertrophy according to the results ECHO}} \times 100$$

The false readings of the ECG are either false negative (hypertrophy present but was not detected) or false positives (hypertrophy was not present but the person was wrongly considered as having hypertrophy).

RESULTS

The difference in age, BSA, SBP, and DBP between athletes and control group did not reach a statistical significance level (P>0.05). (Table-1).

Table 1. General characteristics of study population.

	Athletes		Control		P-value
	Mean ± SD	Range	Mean ± SD	Range	
Age, year	32.4± 4.3	18 – 35	23.6 ± 2.9	18 -35	> 0.05
BSA*, m^2	1.85 ± 0.1	1.5 - 2.1	1.8 ± 0.1	1.6 - 2.1	> 0.05
SBP*, mmHg	120 ± 10.4	90 - 140	121.2 ± 8.9	90 - 140	> 0.05
DBP*, mmHg	76.7 ± 7.1	60 - 90	76.6 ± 7.9	50 - 90	> 0.05

Echocardiographic findings in study population

In present study we found that 37% of our athletes had LVMI > 130 g/m^2 (i.e. LV hypertrophy). But, we did not find any individual in control group with left ventricular mass index exceeded upper normal limit. (Table-2) shows, the distribution of LVMI among athletes and non-athletes control. In athletes group the LVMI ranged from 75.1 to 214.5 g/m^2 (mean 123.9 ± 24.5 g/m^2). In non-athletes group the LVMI ranged from 46.6 to 119.8 g/m^2 (mean 77.1 ± 18.7 g/m^2). The difference between the two groups was found to be highly significant (P< 0.001).

Table 2. LVMI measurement in athletes and control group.

	Athletes		Control		P value
	Mean ± SD	Range	Mean ± SD	Range	
LVMI, gm/m^2	123.9±24.5	75.1-214.5	77.1±18.7	46.6-119.8	< 0.001

Sokolow- Lyon voltage criterion in study population

In this study we found that about 56% of our athletes and only 6% of non-athletes healthy control had Left ventricular hypertrophy. **Figures (2,3),** the value of Sokolow-Lyon voltage criterion in athletes ranged from 18 to 53 mm (mean, 34.7+8 mm). The corresponding value in control group ranged from 11 to 39 mm (mean, 24.5+6.6 mm). The difference in this value between athletes and the control group is highly significant (P< 0.001). (Table-3).

Table 3. Sokolow-Lyon voltage criterion in athletes and control group.

	Athletes		Control		P-value
	Mean ± SD	Range	Mean ± SD	Range	
Sokolow-Lyon criterion, mm	34.7 ± 8	18 – 53	24.5 ± 6.6	11 - 39	< 0.001

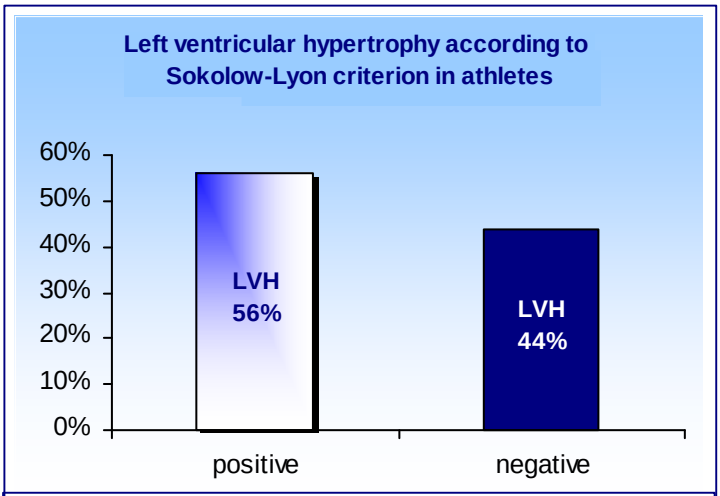

Fig 1. Percentage of athletes with Left ventricular hypertrophy (LVH) according to Sokolow-Lyon voltage criterion. LVH presents when S1+R5 or 6 ≥ 35 mm.

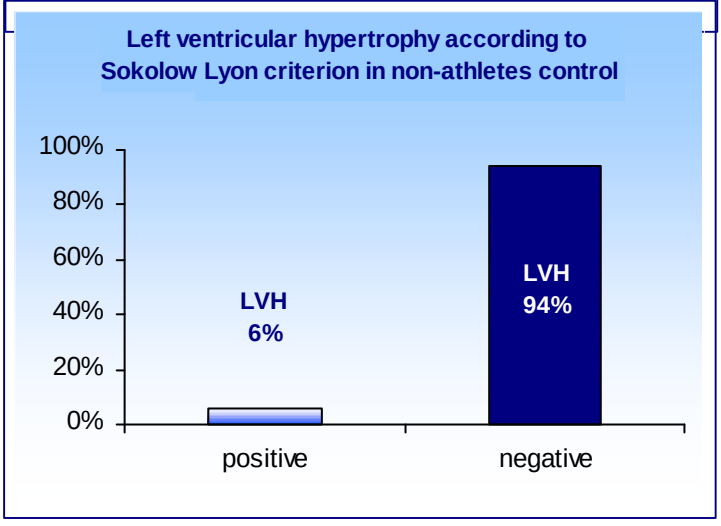

Fig 2. Percentage of non-athletes control with Left ventricular hypertrophy according to Sokolow-Lyon voltage criterion.

Validity of Sokolow- Lyon voltage criterion in athletes

Table-4 shows, the results of the echocardiography and electrocardiography among athletes. The sensitivity of ECG to detect correctly the presence of ventricular hypertrophy is low (63.6%) which means that the ECG missed 36.4% of cases of left ventricular hypertrophy (false negative rate) compared to the results of the echocardiography *(assuming the latter is completely accurate)*. On the other hand, the ECG ability to exclude ventricular hypertrophy among athletes without such condition (specificity) was very low (50.9%). this means that (49.1%) of the non hypertrophic persons by the echocardiography were considered as having ventricular hypertrophy by the ECG *(false positive rate)*.

Table 4. Comparison of the results of Echocardiography with ECG in athletes.

		Echocardiography		
		+	-	Total
ECG	+	21 (63.6%)	28 (49.1%)	49
	-	12 (36.4%)	29 (50.9%)	41
	Total	33 (100%)	57 (100%)	90

Validity of Sokolow – Lyon voltage criterion in control group

When we test the validity of Sokolow Lyon criterion among control group, we found that the specifity rate would increase to 90% when compare with 49% that founding in athletes group. On the other hand, we found that sensitivity rate would increase to 81.8%. (Table-5)

Table 5. Comparison of the results of Echocardiography with ECG in control group.

		Echocardiography		Total
		+	-	
ECG	+	27(81.8%)	5 (9.8%)	32
	-	6(18.2%)	46(90.2%)	52
	Total	33(100%)	51(100%)	84

DISCUSSION

Although echocardiography has become the gold standard for LV hypertrophy detection in clinical practice, ECG remains widely used due to its simplicity and accessibility.[13] For present analysis, Sokolow-Lyon voltage criterion for LV hypertrophy was chosen by authors in consideration of both their general acceptance and recognized performance.[14] This criterion is a pure voltage criterion (i.e., based only on wave amplitude measurements).[8] Many authors used this as a method for assessing LV hypertrophy in the ECG, although it is known that this criterion may be falsely positive in young adult. It is necessary, however, to consider the possibility of false positive results of ECG when compared with echocardiography.[15,16] The problem of false positive was important, because all athletes who tested positive are brought back for more sophisticated and more expensive tests. Of several problems that result, the important one is the anxiety and worry induced in athletes who have been told that they have LV hypertrophy. Based on our data in athletes, Sokolow-Lyon voltage criterion had poor sensitivity (64%) & poor specificity (49.1%). Noticeably, previous studies in general populations resulted in much higher value, in which the specificity of this criterion reaches to 90%-95%.[1,2,8] In the present study, when we calculate the sensitivity and specificity for all study groups (athletes and non-athletes) the specificity improved to 75.9%.

So that, caution should nevertheless be taken when using ECG voltage criteria for LV hypertrophy detection because they exhibit only limited accuracy (generally due to poor sensitivity and very poor specificity).

In present study, we found that the value of Sokolow-Lyon criterion was significantly higher in athletes than in sedentary controls, and 56% of our athletes had LV hypertrophy according to this criterion. The deflections of SVI and RV5 or RV6 average equal or more than 35 mm was found in five of six studies. Athletes commonly meet the criteria for LV hypertrophy, and the condition can be considered physiological and within the normal spectrum for them.[1]

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