Electrocardiographic criteria for left ventricular hypertrophy in professional and non-professional athletes

Critérios eletrocardiográficos para hipertrofia ventricular esquerda em atletas profissionais e não profissionais

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ABSTRACT
Every athlete can be defined qualitatively and quantitatively. Qualitatively, a professional athlete is one who competes in official competitions and who performs constant and systematic training reaching his physical limit during them. In a quantitative way, professional athletes and non-professional athletes are distinguished by the number of hours of training, and professionals practice regular training lasting more than 6 hours per week. (D'Andrea et al., 2018)

Keywords: Electrocardiographic, Left Ventricular Hypertrophy, Athletes.

RESUMO
Todo o atleta pode ser definido de forma qualitativa e quantitativa. Qualitativamente, um atleta profissional é aquele que disputa competições oficiais e que realiza treinos constantes e sistemáticos atingindo o seu limite físico durante os mesmos. De uma forma quantitativa, atletas profissionais e atletas não profissionais distinguem-se pelo número de horas de treino, sendo que os profissionais praticam treinos regulares com duração superior a 6 horas semanais (D'Andrea et al., 2018).

Palavras-chave: Eletrocardiográficos, Hipertrofia Ventricular Esquerda, Atletas.

1 INTRODUCTION

Every athlete can be defined qualitatively and quantitatively. Qualitatively, a professional athlete is one who competes in official competitions and who performs constant and systematic training reaching his physical limit during them. In a quantitative way, professional athletes and non-professional athletes are distinguished by the number of hours of training, and professionals practice regular training lasting more than 6 hours per week. (D'Andrea et al., 2018)

The practice of sports requires greater complexity and various levels of cardiac performance either in different or in the same sport. This is due to several characteristics such as the training practiced and the tactical position. (Emery & Kovacs, 2018)

During the repetitive process of high-intensity training by athletes there are cardiovascular, anatomical or functional adaptations, which consequently can develop physiological or pathological changes. Thus, it is mandatory to correctly identify these modifications, because the existence of underdiagnoses can cause numerous consequences for the athlete. (Brosnan & Rakhit, 2018)

The pathological changes of cardiac remodeling associated with the regular practice of physical exercise can lead to a phenomenon called Sudden Cardiac Death (SCD). In an attempt to identify athletes with greater predisposition to the occurrence of this event, a cardiovascular screening should be performed during the pre-season. Often the focus of this screening is only centered on professional athletes who are most at risk for the occurrence of SCD, but more than 90% of fatal sports-related cardiac events occur in non-professional athletes. (Schmied, 2015)

In an initial phase, the cardiovascular study of the athletes consists of an evaluation of the family history and a physical examination with the inclusion of an electrocardiogram (ECG), since this is more concrete than just an evaluation of the family history. The various electrocardiographic findings in athletes are what makes the ECG analysis more accurate in the evaluation of changes related to CSM. Although several criteria for the evaluation of electrocardiograms in athletes have been tried, all have been replaced by the "International Recommendations on ECG interpretation in athletes", these criteria use the latest scientific evidence to increase specificity while maintaining their sensitivity for the detection of pathological electrocardiographic findings. (Sharma et al., 2017) (Sharma et al., 2017)

Although there are several factors behind CSM, there are some studies that indicate that left ventricular hypertrophy (LVH) is an independent risk factor for this event. LVH is characterized by an increase in left ventricular mass caused by an increase in wall thickness or by an increase in the size of the cardiac chamber. The ECG has a moderate accuracy with regard to the detection and diagnosis of LVH, this examination may also reveal the presence of arrhythmogenic substrate associated with a high mortality . Thus, the presence of LVH on the ECG may help to recognize individuals who have a higher risk associated with CSM. (Giamouzis et al., 2022) (Ferdinand & Maraboto, 2019) (Giamouzis et al., 2022)

For the diagnosis of LVH on the ECG, criteria are used, and there are numerous that exist for possible use in the analysis of the test. However, in a study conducted by Peguero et al. it was found that the Peguero-Lo Presti criterion showed superior sensitivity (70%) when compared to the Cornell and Sokolow-Lyon criteria. (Peguero et al., 2017)

2 GOAL

The main objective of this study is to apply the electrocardiographic criteria of LVH in professional and non-professional futsal athletes and to verify in which of the criteria there is a higher incidence of LVH.

3 METHODOLOGY

3.1 SAMPLE

The sample is divided into 2 groups: 43 professional athletes and 41 non-professional athletes. The following inclusion criteria were assumed: Athletes who do not present contraindications to the practice of sports, athletes without cardiac history, nor carriers of cardiac devices (pacemaker, implanted defibrillator), and athletes who do not take medication that influences the cardiovascular system and aged over 18 years.

3.2 PROTOCOL

Regarding the procedure for data collection, it was performed following the recommendations of the *American Heart Association*, the athlete lay in dorsal decubitus on the marquesa and 4 electrodes were placed on the limbs (these being the classic leads) and 6 electrodes on the chest (horizontal plane leads). The examinations were performed in a (Kligfield et al., 2007) *Schiller AT-4* ® equipment with a calibration of 10mm/mV and printing speed of 25mm/s and filters of 50Hz.

The analysis of the electrocardiograms *was performed based on the most recent* (Sharma et al., 2017) guidelines on the interpretation of electrocardiograms in athletes.

The electrocardiogram analyzed the QRS voltage using the *Sokolow-Lyon*, *Peguero LoPresti and Cornell* criteria.

Peguero-Lo Presti: SVD+SV4 ⩾ 2.8mV (28mm)

***Sokolow-Lyon*:** RV5/V6+SV1 ⩾ 3.5mV (35mm)

***Cornell*:** SV3+RaVL ⩾ 2.8mV (28mm)

If the athlete presented values equal to or higher than those defined in each index, we considered the presence of criteria for LVH.

The presence of LVH using the Romhilt-Estes *criterion is defined as probable LVH or defined LVH using* a Score *consisting of a scoring system.* (Hamed et al., 2022)

Table 1. Score using the criterion of Rohmilt-Estes to determine the existence of LVH.

	PUNCTUATION
R wave or S wave amplitude ⩾ 2.0mV (20mm) in classical leads OR S wave ⩾ 3.0 mV (30mm) in V1/V2 OR R wave ⩾3.0 mV (30mm) in V5/V6	**3 Points**
ST-segment depression in the opposite direction to the QRS complex:	
No Digitalis	**3 points**
With Digitalis	**1 Point**
Involvement of the left auricle: Negative part of the P wave in V1 with amplitude ⩾ 0.01mV and duration ⩾0.04 seconds	**3 Points**
Left Axis Deviation ⩾ -30°	**2 Points**
Duration of the QRS complex ⩾ 90 milliseconds	**1 Point**
Interval Q-R ⩾ 50 milliseconds in V5/V6	**1 Point**
Final diagnosis	***TOTAL***
Probable LVH	**4 Points**
HVE Defined	**5 Points**

Legend: mm – mm; mV – millivolt; LVH – Left Ventricular Hypertrophy; º- Degrees

3.3 COLLAPSED VARIABLES

To fulfill the objective of the investigation, several quantitative variables were collected, including age in years, weight in kilograms (kg), height in centimeters (cm), data that were obtained by conducting an individual questionnaire to the athletes to later calculate the Body Mass Index (BMI) in Kg/m2. The QRS amplitude in millimeters (mm) using the criteria to determine LVH (*Peguero-Lo Presti*, *Sokolow Lyon*, *Cornell*) on the electrocardiogram, previously described.

Qualitative variables such as the race of the athletes were also collected by completing an individual questionnaire for each athlete, which were divided into Caucasian, African and brown races and the possible presence of LVH (yes or no) following the criteria described above. (Davis et al., 2022)

3.4 STATISTICAL ANALYSIS

Statistical analysis was performed using version 27 of the Statistical *Product and Service Solutions software*, *SPSS® for IBM Windows®*. For data processing, a descriptive analysis was performed using absolute (n) and relative frequencies, in percentage (%) for qualitative variables and using measures of central tendency (mean) and dispersion (standard deviation).

For the analysis of quantitative electrocardiographic variables, the *Mann-Whitney U* test was used, however for qualitative variables the *Chi-Square test was used.*

To assess whether the quantitative variables are dependent on the degree of professionalism, the *nonparametric Mann-Whitney U* test and the parametric *t-student test were used*.

To assess whether the presence of LVH, according to the various criteria, is dependent on the degree of professionalism, the *Chi-Square test was used*.

A *p-value* less than or equal to 0.05 was defined as statistically significant for all tests performed.

3.5 ETHICS

Data collection was initiated after a positive opinion from the ethics committee of the Polytechnic Institute of Castelo Branco.

This study respected and preserved the confidentiality of all data and information collected. All information related to the individuals included in the investigation was coded, making it impossible to identify them.

The investigation team declares that it has no conflicts of interest and undertakes to respect the principles expressed in the Declaration of Helsinki. This research is not for profit or commercial.

4 FINDINGS

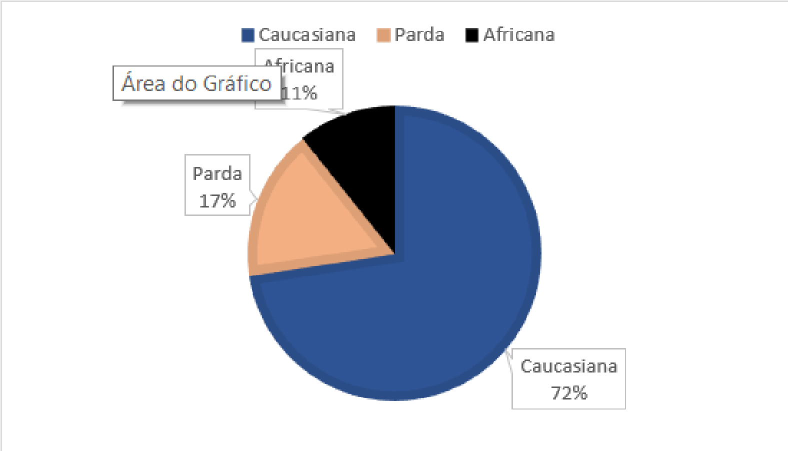
4.1 SAMPLE CHARACTERIZATION

The sample is composed of 84 athletes, aged between 18 and 40 years, with an average value of 25.4 ± 5.3 years. In professional athletes the average age is 24.9 ± 5.0 years and in non-professional athletes the average is 25.8 ± 5.6 years.

The mean BMI is 23.1 kg/m2. In the group of professionals the mean BMI value is 23.53 ± 1.54 Kg/m2, in the group of non-professionals the value is 22.83 ± 4.11 Kg/m2.

Of the total sample, 43 athletes are professionals and 41 non-professional athletes, of which 61 are Caucasian, 9 African and 14 brown athletes.

Graph 1 – Distribution of the whole sample by race



4.2 EVALUATION OF VOLTAGE AVERAGES USING LVH CRITERIA RELATING THE DEGREE OF PROFESSIONALISM

Table 2 shows that non-professional athletes in the *Peguero-Lo Presti criterion (*26mm vs 21mm) and Cornell criterion (14mm vs 9mm) present higher QRS voltages when compared to professional athletes, with a statistically significant difference. However, in the *Sokolow-Lyon* criterion the mean voltage of the QRS complex is equal in both groups (29mm), without statistical significance.

Table 2 – Mean QRS Voltage Value using the Peguero-Lo Presti, Sokolow-Lyon and Cornell criteria

	Atletas Profissionais	Atletas Não Profissionais	*p-value*
Voltagem QRS Peguero-Lo Presti	21±8 mm	26±7 mm	*p=0,005**
Voltagem QRS Sokolow-Lyon	29±8 mm	29±7 mm	*p=0,977*
Voltagem QRS Cornell	9±5 mm	14±5 mm	*p<0,0001**

Legend Table 2: mm – mm; Tests used: Mann-Whitney you and t-student; *statistically significant difference (p<0.050)

4.3 EVALUATION OF THE PRESENCE OF LVH AMONG PROFESSIONAL AND NON-PROFESSIONAL ATHLETES

After applying the various electrocardiographic indices of LVH, it is observed that of the 84 athletes in the sample, 32% have LVH applying the *Peguero-Lo Presti criterion, where 18 athletes are non-professionals and 9 are professionals, 34% with the* Rohmilt-Estes (22 professionals *and 12 non-*

professionals), 28% using the Sokolow-Lyon index (13 professional and 11 non-professional athletes), and none of the athletes presented criteria for LVH using the *Cornell index*.

Of all the indices used, statistically significant differences were found between professional and non-professional athletes, in the *Peguero-Lo Presti criterion* and in the *Rohmilt-Estes criterion*, as can be seen in table 3.

Table 3 – Number of athletes who meet the electrocardiographic criteria for LVH using the Peguero-Lo Presti, Sokolow-Lyon, Cornell and Rohmilt-Estes indices

χ	Critério HVE Peguero-Lo Presti (n)	Critério HVE Sokolow-Lyon (n)	Critério HVE Cornell (n)	Critério HVE Rohmilt-Estes (n)
Atletas Profissionais	9 Atletas	13 Atletas	0 Atletas	22 Atletas
Atletas Não Profissionais	18 Atletas	11 Atletas	0 Atletas	12 Atletas
p-value	*p=0,024**	*p=0,730*	Não Aplicável	*p=0,042**

Test used: Chi-Square; *statistically significant difference (p<0.050)

5 DISCUSSION

The presence of electrocardiographic criteria for LVH is an established risk factor for the occurrence of cardiovascular events, and in addition to this fact LVH is also associated with CSM. Since the electrocardiogram is one of the main routine exams, the search for electrocardiographic findings compatible with LVH is a key point in the interpretation of the test, and for this purpose several criteria were developed to identify this alteration. In carrying out this study, from the various existing indices, those of (Giamouzis et al., 2022) (Marcato et al., 2022; Porthan et al., 2019) *Peguero-Lo Presti, Sokolow-Lyon, Cornell and* Romhilt-Estes *were selected, since these are the criteria with the highest specificity and sensitivity in the evaluation of LVH when using this means of diagnosis.* (Peguero et al., 2017)

First, with the results obtained, it was verified that non-professional athletes have higher mean values of QRS complex voltages than professional athletes using the criteria of *Peguero-Lo Presti* and *Cornell*. In turn, in the *Sokolow-Lyon criterion*, the mean voltage values were identical in both groups. It is known that BMI is one of the numerous factors that can influence several electrocardiographic findings, such as the voltage of the QRS complex, where with the increase in BMI there is a decrease in the voltage of the QRS complexes and vice versa, since the distance from the electrode to the myocardium increases with the increase in adipose tissue. In this study, analyzing the mean values of BMI, it is possible to observe that non-professional athletes present a lower mean value than the other group, which may justify the increase in voltage of the QRS complexes in non-professional athletes. (Hassing et al., 2019)

Our results are corroborated by the research conducted by *Hassing et al.*, which using a sample of young people with a BMI between 18.5 and 25 kg/m2, found that those with higher BMI had some electrocardiographic changes, including a decrease in the amplitude of the QRS complexes using the *Sokolow-Lyon criterion* (Hassing et al., 2019) .

In turn, *Hedman et al.* tried to understand how the relationship between the voltage of the QRS complexes and the mass of the left ventricle is affected by the distance between the chest and the left ventricle. In this article it was found that the distance between the chest and the left ventricle, although poor, is an independent predictor of the voltage of the QRS complexes on the electrocardiogram and may contribute to a poor diagnosis of LVH using the various electrocardiographic criteria. (Hedman et al., 2020)

According to what is described in the literature, the cardiac adaptation of athletes to exertion causes changes in the cardiac cavities. Associated with repetitive and constant training, there is an increase in these structures and their thickness, which is later reflected in the electrocardiogram. Although there is an isolated increase in QRS voltage in 45% of cases, this in the absence of other abnormal changes, is not in itself an indication of LVH. (Huttin et al., 2018)

Analyzing the results obtained for the incidence of LVH using the various selected criteria, professional athletes present a greater number of athletes with possible LVH, using the *Sokolow-Lyon* and *Romhilt-Estes* criteria, however, when applying the *Peguero-Lo Presti* criterion we verified that the same is not verified, observing then that with the use of this criterion, the group of non-professional athletes presents a greater number of athletes with the presence of LVH.

In the *Peguero-Lo Presti* criterion an evaluation is made by the sum of the deepest S wave with the S wave in the V4 derivation. As is known, in the electrocardiogram the deepest S wave can appear in the V2 lead or in the V3 lead. Thus, we can say that in non-professional athletes, due to the higher incidence of LVH by the *Peguero-Lo Presti* criterion, this may be related to a thickening of the anterior wall, which translates into an increase in voltage in these leads. (Bayram et al., 2021; Meek & Morris, n.d.)

In a meta-analysis conducted by *Zongying Yu* et al. it was discussed that although the *Peguero-Lo Presti* criterion has a better diagnostic performance than the other indices, its performance is influenced by the relative thickness of the cardiac walls. (Yu et al., 2021)

In turn, in the *Sokolow-Lyon* criterion where the evaluation of the presence of LVH is made using the sum of the R wave of V5/V6 with the S wave of V1, thus having a possible involvement of the lateral wall and the septal wall, we can only suspect, due to the absence of echocardiography, that professional athletes present a greater thickening of the septal wall and/or the lateral wall associated with regular practice of high-intensity workouts. (Holiday et al., 2021)

Weberruß et al. found that a higher aerobic capacity significantly influences the thickness of the septal wall in diastole, as well as a higher training intensity influences the ventricular diameter in systole and diastole. (Weberruß et al., 2022)

With the use of the *Cornell* criterion it was found that no athlete from both groups present voltage criteria for the presence of LVH, however in a meta-analysis conducted by *Zhigang You* et al. it was found that the LVH detected through this criterion has a higher predictive value in mortality from cardiovascular disease. This criterion was applied to the general population and it was found that 87% of the population had a higher risk for death from all causes, 66% had a higher risk for cardiovascular death and 70% had a higher risk for major cardiovascular events. (You et al., 2020)

Observing the results obtained in relation to the *Romhilt-Estes* criterion, it is possible to observe that there are 22 professional athletes *who present a score* of 4 points corresponding to probable LVH against 12 non-professionals who present probable LVH. None of the individuals in the sample had a definite diagnosis of LVH. *Hamed et al*. suggested that this criterion is a more reliable and safe method than the *Sokolow-Lyon* and *Cornell criteria*, which are based only on the voltage of the QRS complexes. It has further been discussed that *a score* greater than 4 points is associated with a higher risk of cardiovascular disease, coronary heart disease, heart failure and others. (Hamed et al., 2022)

This investigation has some study limitations, such as the lack of articles and investigations using these LVH criteria comparing two groups of athletes and the absence of echocardiogram to verify the specificity of the various criteria for LVH using the electrocardiogram.

6 FINAL CONSIDERATIONS

Professional athletes have a higher prevalence of LVH using the Sokolow-Lyon and Romhilt-Estes criteria, although the mean values are lower than those of non-professionals. Due to the diversity of results, it is important to apply the various indices when studying LVH in athletes.

In the future, it would be interesting to study this sample using transthoracic echocardiography in order to verify the sensitivity and specificity of the electrocardiographic criteria applied and to ascertain which is the most appropriate to evaluate LVH in young athletes.

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