Revision of the Sokolow-Lyon-Rappaport and Cornell Voltage Criteria for Left Ventricular Hypertrophy

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Summary

Background: Electrocardiographically-detected left ventricular hypertrophy (LVH) is a strong predictor of cardiovascular morbidity and mortality.

Objective: To assess the performance of the Sokolow-Lyon-Rappaport (SLR) and Cornell voltage criteria in a population sample regarding the diagnosis of LVH on echocardiogram (ECHO).

Methods: A total of 641 out of the 682 participants of the second phase of the MONICA-Vitória project were assessed using electrocardiogram and echocardiogram. A subgroup of healthy individuals (n=269) was used to generate reference values of LV mass (LVM). Sensitivities and specificities of the electrocardiographic criteria were determined by the ROC (receptor-operator characteristics) curve in relation to the diagnosis of LVH, as defined by the internal echocardiographic criterion (LVM ≥48 and 46 g/m² for males and females, respectively).

Results: The prevalence of LVH as detected by ECHO was 23.7% in the total sample, in which 49% of the individuals were hypertensive. The Cornell criterion showed a better association with the LVM as estimated by ECHO (r= 0.37, p < 0.01) than the SLR criterion (r= 0.19) as well as a better performance in the analysis of the area under the ROC curve. The new cut-off points for the internally-defined Cornell voltage criterion (2.3 mV for males and 1.9 mV for females) showed an acceptable combination of sensitivity (22.5 and 28% for males and females, respectively), with a high specificity (95%).

Conclusion: The classic SLR and Cornell voltage criteria showed a low performance in relation to LVH as detected by the ECHO. However, this accuracy may be improved by using the Cornell voltage criteria defined in the present study.

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Key words: Electrocardiography; echocardiography; hypertrophy, left ventricular; hypertension.

Introduction

Electrocardiographically (ECG)¹² - or echocardiographically (ECHO)³⁴ - detected left ventricular hypertrophy (LVH) is a manifestation of preclinical⁵ cardiovascular disease and a strong predictor of cardiovascular morbidity and mortality. The diagnosis of LVH should preferably be made using echocardiography. However, technical difficulties and economic considerations restrict the large-scale use of ECHO for this purpose. Resting ECG, on the other hand, is a low-cost, non-invasive, easy-to-acquire method that is widely available for clinical use. Many studies have been conducted to improve electrocardiographic criteria for the identification of this condition in patients with different cardiovascular diseases. The major criterion for the identification of LVH is the increased QRS-complex voltage, and several criteria have been proposed for this purpose. Reports of superiority of the Cornell criterion over the classic Sokolow-Lyon criterion have been published⁶. However, most of the studies that established cut-off points to separate individuals with normal left ventricular mass from those with LVH were conducted in the North American population. The simple extrapolation of these criteria to other populations can lead to a significant error, since the QRS voltage depends not only on the cardiac mass, but also on anthropometric data, on fat deposition in the upper body, and on breast size in women.

Considering that ECG is still the main tool for the diagnosis of LVH in most health services, especially in those linked to the public network focused on primary care, the objective of this study was to determine values of Sokolow-Lyon-Rappaport⁷⁸ and Cornell¹⁰ voltage criteria in a general population sample included in an epidemiological study conducted in the city of Vitória, ES, (WHO-MONICA Project/Vitória)¹¹¹² with the purpose of determining the prevalence and severity of cardiovascular risk factors. The study enabled the definition of new cut-off points for LVH on ECG, using ECHO findings (M-mode guided by the two-dimensional mode, using images
generated by the second harmonic) as the gold standard. By analyzing the ROC curves, sensitivity and specificity values could be determined in males and females at different cut-off points obtained in the electrocardiographic recordings.

**Methods**

The study was conducted in a sample of 682 individuals of both genders (43.5% males), aged between 27 and 72 years, who participated in the second phase of the WHO-MONICA Project/Vitória. All participants were from a random sample (N = 1663) of the population of the city of Vitória studied in phase 1 of the same project in the years 1999/00\textsuperscript{11,12}. The individuals were invited via phone calls and/or mailing to undergo new clinical and laboratory tests at the University Hospital of UFES. The research protocol was approved by the Research Ethics Committee of the Health Sciences Center of UFES and a written informed consent form was obtained from all participants. All individuals were classified as regards race according to criteria validated in the Brazilian population\textsuperscript{13}. Based on phenotypic characteristics (skin color, hair texture, nose shape, and aspect of the lips) and on self-assessment, the individuals were classified as white, black, mulatto, or other mixtures.

Conventional resting electrocardiogram (ECG) (12-lead) was performed in 681 individuals on a PC-based equipment (Ecafix, model Cardio Perfect) with record printing on a HP682C printer (0.1 mV/cm and 25 mm/s). The Sokolow-Lyon-Rappaport\textsuperscript{8,9} (SLR) index ($SV_1$ or $V_2 + RV_4$, or $V_7 \geq 3.5$ mV or 35 mm) and the Cornell\textsuperscript{6,10} criteria ($RaVL + SV_3 \geq 2.8$ mV or 28 mm, and/or $2.4$ mV or 24 mm for males and $\geq 2.0$ mV or 20 mm for females), hereafter called “external criteria”, were used to assess LVH. ECG recordings with complete bundle branch block, myocardial infarction, Wolff-Parkinson-White syndrome, atrial fibrillation, and use of digitals were excluded.

The tests were performed in the Acuson-Sequiao equipment from the echocardiography service of the University Hospital of UFES. All tests were performed by a single observer with a ten-year experience in echocardiography and blinded to the individuals’ clinical and laboratory data. A total of 35 randomly chosen tests were analyzed by a second observer and the results showed Pearson’s correlation coefficients ($r$) of 0.94 for septal thickness and LV diastolic diameter, 0.92 for posterior wall thickness, and 0.89 for LV systolic diameter.

Images were obtained with the participants in the left lateral position, in the parasternal long-axis and short-axis views, and in the four and two-chamber apical views. Only tests with proper interface visualization that showed simultaneous images of the septum, LV inner diameter and posterior wall were considered adequate for determination of the LVM. A total of 41 individuals were excluded because they did not undergo ECG and/or ECHO. LV measurements were taken according to the recommendations of the American Society of Echocardiography (ASE)\textsuperscript{14}, with the M-mode guided by the two-dimensional mode, using the image resource generated by the second harmonic imaging. LV measurements were taken on the equipment screen, with a 2-mm resolution, following the “leading edge to leading edge” convention\textsuperscript{14}. LV systolic and diastolic diameters, interventricular septal and LV posterior wall thickness were measured at end-diastole, which was defined by the beginning of the QRS complex as monitored by simultaneous electrocardiography. All values were recorded in millimeters (mm), and each measurement was recorded as the mean of three consecutive measurements. LVM was calculated using the corrected ASE formula\textsuperscript{15}:

$$LVM = 0.8 \times (IVS + LVDd + PW) - LVDd^2 + 0.6g$$

where IVS stands for interventricular septum thickness, LVDd for LV diastolic diameter, and PW for posterior wall thickness.

LVM was indexed for body surface (calculated by the Dubois formula\textsuperscript{16}), for height (meters), and for height elevated to the 2.7 power, as recommended by De Simone et al\textsuperscript{17,18}. Measurements used to generate the internal values were obtained from a healthy subsample comprised of 269 individuals who were not receiving medication for hypertension and/or diabetes, and whose blood pressure was $<140/90$ mmHg, BMI $<30$ kg/m$^2$, blood glucose $<110$ g/dl, creatinine $<2.0$ mg/dl, SLR index $<3.5$ mV, and who did not have valvular lesions or myocardial wall motion abnormalities. The cut-off points were defined as the values corresponding to the 95% percentile ($P_{95}$) of the normal distribution curve, and were $\geq 48$ and 46 g/m$^2$, $\geq 110$ and $98.7$ g/m$^2$, and $\geq 105$ and 95.3 g/m$^2$ for males and females, respectively. Hereafter we will use the LVM indexed for height$^{2.7}$ for the comparisons with ECG criteria.

Statistical analysis - Data are expressed as mean $\pm$ standard deviation (sd) for continuous variables and as proportions for categorical variables. The means $\pm$ sd were calculated for indexed LVM and for each electrocardiographic criterion according to gender and the presence of LVH. The differences in prevalences between the groups were analyzed using the Z test for proportions\textsuperscript{19}. Analysis of performance of LVM indexers and of sensitivities and specificities of the SLR and Cornell indexers were made using the ROC curve\textsuperscript{20}. The differences of performance of the areas under the ROC curve were compared using the univariate and two-tailed Z score\textsuperscript{21}. Sensitivities were also compared at a fixed specificity level of 95%, and the corresponding cut-off point values were identified for each criterion. The $t$ test or one-way Anova were used to compare two or more means. The post-hoc Tukey test was used when necessary. The degree of correlation between the SLR and Cornell criteria and the LVM was determined using the Pearson $r$ coefficient. The statistical significance was set at $p < 0.05$ in a SPSS 13.0 software program analysis.

**Results**

Of the 682 individuals studied, 43.5% were males, of which 17.1% were white, 21.8% were mulatto, and 2.9% were black. A total of 56.5% were women, of which 19.9% were white, 28.7% were mulatto, and 2.7% were black. For 641 individuals, both ECG and ECHO were technically adequate.

In the total sample (Table 1), we verified that all continuous variables were significantly different between genders, except for age, indexed LVM, LVDd, and IVS and PW thickness. For categorical variables, the differences did not reach statistical significance, despite the higher prevalence of diabetes among
females and of smoking among males. However, we observed differences in the prevalence of obesity (higher among females), as well as a greater trend of hypertension among males, associated with a less frequent use of antihypertensive drugs. In the healthy subsample, the mean values of all continuous variables were significantly higher in males, except for age, BMI, IVS and PW thickness, and LVDd. The prevalence of smoking was equal in the two genders.

LVM indexed for height to the 2.7 power (g/m^2.7) was positively correlated (p<0.01) with the Cornell (r = 0.37) and SLR (r = 0.19) criteria (Figures 1, A and B).

Table 2 shows that males have higher voltage values than females for both criteria (SLR and Cornell), both in the groups with and without LVH, except for the Cornell criterion in the group with LVH.

Table 2 - Characteristics of the total sample and of the reference healthy subgroup

<table>
<thead>
<tr>
<th></th>
<th>Total sample</th>
<th>Healthy sample</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Males (n=297)</td>
<td>Females (n=385)</td>
</tr>
<tr>
<td>Age, years</td>
<td>51.3 (10.5)</td>
<td>51.2 (10.2)</td>
</tr>
<tr>
<td>Weight, Kg</td>
<td>74.7 (11.5)</td>
<td>65.4 (13.5)*</td>
</tr>
<tr>
<td>BMI, Kg/m^2</td>
<td>26.1 (3.6)</td>
<td>26.8 (5.2)*</td>
</tr>
<tr>
<td>BS, m^2</td>
<td>1.84 (0.15)</td>
<td>1.64 (0.18)*</td>
</tr>
<tr>
<td>SBP, mmHg</td>
<td>133.8 (18.5)</td>
<td>127.5 (19.4)*</td>
</tr>
<tr>
<td>DBP, mmHg</td>
<td>88.6 (11.5)</td>
<td>82.4 (11.8)*</td>
</tr>
<tr>
<td>SLR, mm</td>
<td>28.8 (9.0)</td>
<td>23.4 (6.9)*</td>
</tr>
<tr>
<td>Cornell, mm</td>
<td>15.5 (5.8)</td>
<td>13.2 (5.8)*</td>
</tr>
<tr>
<td>LVM, g</td>
<td>170.9 (44.7)</td>
<td>136.4 (6.8)*</td>
</tr>
<tr>
<td>BMI &gt;30Kg/m^2 %</td>
<td>15</td>
<td>24</td>
</tr>
<tr>
<td>Smokers,%</td>
<td>19.8</td>
<td>14.8</td>
</tr>
<tr>
<td>Diabetes,%</td>
<td>4.3</td>
<td>7.6</td>
</tr>
<tr>
<td>Hypertensive/AH%</td>
<td>55.5/24.5</td>
<td>43.6/30.3</td>
</tr>
</tbody>
</table>

Values expressed as means (standard deviation). The reference healthy sub-sample is comprised of individuals without cardiovascular disease, obesity, diabetes or renal dysfunction. BMI - body mass index; BS - body surface; SBP and DBP - systolic and diastolic blood pressure; SLR - Sokolow-Lyon-Rappaport on ECG; LVM - left ventricular mass on echocardiogram. IVS - interventricular septum; PW - posterior wall; LVDdVE - left ventricular diastolic diameter; AH - on antihypertensive medication. P< 0.05 vs. males from the same sample.

The Cornell voltage criterion is similar to that of SLR in males, but is higher in females (28% vs. 20%). The comparison of SLR and Cornell indexes between the ethnic-racial groups of the total sample is shown in Figure 3. Despite the small number of black individuals (only 39), we can verify that black individuals and mulattoes presented mean SLR values higher than white individuals (p<0.05). There is a trend of increased values for the Cornell index in the black race, which, however, does not achieve statistical significance.

The comparison of mean indexed LVM of individuals with a Cornell criterion positive for LVH (≥2.3 mV for males and ≥1.9 mV for females) with indexed LVM of healthy individuals is shown in Table 4. We can notice that both in males and in females the Cornell criterion detects individuals with LVM +2 standard deviations of the mean found for individuals without LVH. The same results are observed for the SLR index using the internal criterion.

**Discussion**

Although ECG is recommended in the assessment of all hypertensive individuals, its use in the diagnosis of LVH is limited because of the low sensitivity of the method. As a consequence, the low prevalence of LVH in population studies resulted in the non-utilization of ECG as a method to determine the presence of LVH in some algorithms.
LV hypertrophy: new SLR and Cornell indexes

Fig. 1 - Correlation of LVM indexed for height2.7 and Sokolow-Lyon-Rappaport (A) and Cornell (B) voltage indexes with regression curves and 95% confidence intervals.

Table 2 - QRS complex voltage and presence of LVH as defined by echocardiogram

<table>
<thead>
<tr>
<th>ECG criterion</th>
<th>Without LVH</th>
<th>With LVH</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLR (mm)</td>
<td>Males</td>
<td>28 ± 8</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>23 ± 6*</td>
</tr>
<tr>
<td>Cornell (mm)</td>
<td>Males</td>
<td>15 ± 5</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>12 ± 6*</td>
</tr>
</tbody>
</table>

Data are expressed as means ± standard deviation. The presence of left ventricular hypertrophy (LVH) was defined by echocardiography using the g/m².7 index (≥48 g/m² for males and females, respectively). (*) p<0.05 between genders.

Fig. 2 - ROC curve comparing the performance of the Sokolow-Lyon-Rappaport (SLR) and Cornell indexes for the identification of LV hypertrophy defined from the LV mass as determined by echocardiography (LVM ≥48 g/m².7 and 46 g/m².7 for males and females, respectively). Regardless of the specificity level, the Cornell criterion is more sensitive.

of cardiovascular risk assessment. Only a small part of individuals with echocardiographic LVH may be detected by ECG at high levels of specificity. However, the ECG is still much more readily available in our setting than ECHO. Additionally, since ECG is a low-cost and easy-to-record method, it is still necessary to try to improve its use for a better identification of individuals with LVH who are included in the group at a high risk of developing more severe cardiovascular end points (cardiac arrhythmias, sudden death, myocardial infarction and others). Individuals at a high cardiovascular risk are known to require increased pharmacological and health care. Thus, in this study we analyzed the voltage criteria of the SLR and Cornell indexes because they are the most widely used in the literature and they also do not demand a PC-based analysis, which makes them more realistic and easy to use in our population.

Studies that have reported high sensitivity values for electrographic criteria were conducted in patients with cardiovascular diseases who had higher LVM values. Gasperin et al studied a sample from the echocardiography outpatient service of a university hospital and verified a low overall performance of the criteria studied; also, the performance of the SLR criterion was even worse than that of Cornell.

The association between ECG voltages and LVM estimates
LV hypertrophy is usually weak\(^6\),\(^23\). However, the LVM indexed by height\(^2.7\) in the total sample showed a significant correlation (p<0.01) with the Cornell and SLR criteria (r = 0.37 and r = 0.19, respectively), with a clear trend of a better association with the first criterion. A similar finding was presented by Schillaci and Porcellati\(^32\) in a study with 923 hypertensive individuals, in which they found correlation coefficients of 0.48 and 0.27 for the Cornell and SLR criteria, respectively. The present study corroborates studies of the literature reporting that the standard electrocardiographic criteria have a low sensitivity in the screening of LVH. On the other hand, for the first time a population-based study conducted in Brazil assesses the performance of these criteria for the diagnosis of LVH using the ROC curve, whose major differential is the possibility of determining the sensitivity for any given specificity value.

The analysis of sensitivity and specificity of a method depends on the cut-off point chosen. The analysis of the area under the ROC curve\(^20,21\) allows the assessment of the performance of one or more tests under a large margin of possible cut-off points, thus permitting the identification and comparison of the differences of performances between methods, regardless of empirically defined criteria. By using this methodology, the present study confirms the superiority of the Cornell criterion over the SLR criterion, as shown in Figure 2, thus corroborating the findings of other studies\(^9,28,32\). For a more clear analysis of the performance of the criteria studied, sensitivities were compared in relation to a fixed specificity level of 95% which, in addition to being the most widely used in the literature\(^22,23\), also reaches the clinical purposes of the method (Table 3). The sensitivity of the Cornell criterion is similar to that of the SLR criterion in males, but is higher in females (28% vs. 20%).

The specific cut-off points for each gender, according to the conventional Cornell criterion (2.8 mV for males and 2.0 mV for females), are based on the evidence that there is a significant difference in the magnitude of QRS voltages between genders\(^6\). However, the analyses of the ROC curve in our sample, as well as the values of mean QRS voltages (Table 2), indicate that this difference seems to be excessive. A smaller difference between voltages (2.3 mV for males and 1.9 mV for females) is associated with a 22.5% sensitivity in males and 28% in females, still maintaining a very good specificity (95%). These values

Table 3 - Sensitivities of the Sokolow-Lyon-Rappaport (SLR) and Cornell voltage criteria and cut-off points for males and females at the specificity level of 95% in the diagnosis of LV hypertrophy as established by echocardiography

<table>
<thead>
<tr>
<th>ECG criterion</th>
<th>Males</th>
<th>Females</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLR</td>
<td>21.4</td>
<td>20.0</td>
<td>≥4.1</td>
<td>≥3.1</td>
</tr>
<tr>
<td>Cornell</td>
<td>22.5</td>
<td>28.0</td>
<td>≥2.3</td>
<td>≥1.9</td>
</tr>
</tbody>
</table>

LV hypertrophy was defined as a LV mass ≥ 48 g/m\(^2.7\) and 46 g/m\(^2.7\) for males and females, respectively.

Table 4 - Indexed left ventricular mass (LVM) of individuals with Cornell criterion positive for LV hypertrophy (≥2.3 mV for males and ≥1.9 mV for females)

<table>
<thead>
<tr>
<th>Indexation Criterion</th>
<th>With LVH</th>
<th>Without LVH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males</td>
<td>Females</td>
</tr>
<tr>
<td>LVM/hei</td>
<td>120 ± 32</td>
<td>110 ± 34</td>
</tr>
<tr>
<td>LVM/bs</td>
<td>109 ± 26</td>
<td>101 ± 29</td>
</tr>
<tr>
<td>LVM/hei(^2.7)</td>
<td>51 ± 15</td>
<td>53 ± 17</td>
</tr>
</tbody>
</table>

The LVM obtained by echocardiography was indexed by height in meters (hei), body surface (bs) and height to the 2.7 power. Values are expressed as means ± standard deviation.
are closer to those established in the study conducted by Schillaci et al\textsuperscript{32}, who proposed values of 2.4 mV and 2.0 mV for males and females, respectively. In a recent publication, Allakih et al\textsuperscript{33} used the analysis of the areas under the ROC curve and proposed a redefinition of the cut-off points stratified by gender for several ECG criteria for the diagnosis of LVH, taking the LVM, as measured by cardiac MRI, as a reference.

Discrepancies in the voltage criteria may be due to differences in ages and clinical conditions of the individuals studied. The cut-off values generated in Casale and Devereux\textsuperscript{34} and Devereux and Eisenberg\textsuperscript{35} studies were obtained from a sample of young normotensive individuals. The mean age in our sample was 51 ± 10 years and, since healthy individuals and those with different diseases such as hypertension were included, the sample probably translates, in a better way, the diagnostic potentialities of the method in daily activities of health care for the population.

The differences in the magnitude of the QRS complex regarding gender are partly attributed to a lower myocardial volume in females and also to the longer distance between the cardiac mass and the precordial leads, because of the breast tissue. The electric potential recorded on the body surface may be attenuated by several extracardiac factors, such as physical constitution, adiposity, pulmonary volume and epicardial fat.

The better performance of the Cornell voltage criterion may be explained by the analysis of vectorcardiographic changes induced by LVH. With the increased LVM, the electric forces become oriented both horizontally (corresponding to the R wave in aVL) and posteriorly (S wave in V3). Additionally, the V3 lead is closer to the left ventricle and is probably less influenced by variations in the distance between the myocardium and the leads\textsuperscript{36}.

Okin and Dahlöf\textsuperscript{37} investigated the values of voltages and of the product (voltage \times QRS duration) of the ECG criteria (Sokolow-Lyon, Cornell voltage and 12-lead sum) among races. After the analysis of results of hypertensive individuals (120 Afro-Americans and 751 white individuals), they found that both the Sokolow-Lyon and the 12-lead-sum criteria overestimated the presence of LVH. Additionally, the Cornell product criterion underestimated the presence of LVH in black individuals in relation to white individuals. These findings resulted from the differences in the mean voltages; the SL index was higher in black individuals (39.0 ± 12.3 vs. 31.7 ± 10.2, p < 0.01), whereas the Cornell index was higher in white individuals (22.7 ± 9.1 vs 25.1 ± 7.8, p < 0.05). Despite the small number of black subjects in our study, we could observe that these individuals presented significantly higher voltage values for the SLR criterion than the mulattoes who, in turn, presented higher values than white individuals. There was an upward trend in the mean Cornell index values in the black race. Because we were comparing voltage criteria between races and found diametrically opposed values, we did not make any adjustments. We did not find an explanation for these differences in the SLR and Cornell indexes within the same race verified in our study and, mainly, for the differences between the criteria applied, since both are voltage criteria.

Okin and Dahlöf\textsuperscript{37} and Chapman and Poulter\textsuperscript{38} reported that the differences in the height of QRS complexes among races could not be explained based on the higher LVM values in Afro-Americans, since the differences persisted even after adjustment for the different LVM. They also reported that the differences in the ECG data did not result from BMI variations, since black individuals tend to have a higher fat mass in the USA, which would result in decreased magnitude, and not increased ECG voltages. In the present study, we did not find differences in mean LVM as estimated by ECHO among the race-ethnicities, nor did we find differences in BMI, perhaps because of the small sample representing the black race. These studies clearly show the need to define race-specific cut-off points for the SLR criterion for the diagnosis of LVH. Also, in this respect, the Cornell criterion was superior because it was independent of the ethnic-racial stratification. This fact is especially relevant in our population, where a great miscategorization is observed, and where there are places in which the black race still predominates in the general population.

Mean LVM values are significantly different between individuals with voltage criteria for LVH in relation to healthy individuals (Table 4). We can observe that in both genders the Cornell criterion detects individuals with LVM +2 standard deviations above normal. We observed the same results for the SLR indexes using the internal criterion. The SLR and Cornell criteria defined in the literature, on the other hand, only identified LVM values 2.5 to 3 standard deviations above the mean. Therefore, the cut-off point defined internally is in tune with the need for diagnostic criteria that are able to detect LVH in earlier phases.

We found a LVH prevalence using the LVM criterion indexed for height to the 2.7 power (g/m\textsuperscript{2.7}) of 23.7% (8.7% in males and 14.9% in females). In this group with LVH identified by ECHO (n = 152), we also found an association of LVH diagnosed by ECG in 29% of the cases (Cornell criterion 2.3 mV and 1.9 mV for males and females, respectively). Thus we verified a good sensitivity with a very good specificity in this new cut-off point for the Cornell criterion. This finding is of the utmost importance, in light of Kohsaka and Di Tullio\textsuperscript{37} that showed an increased risk of ischemic stroke in individuals with LVH diagnosed by ECHO, who also had evidence of LVH using the Cornell electrographic criterion (2.8 mV and 2.0 mV for males and females, respectively). It seems that information obtained from ECG provides independent information on myocardial alterations. The authors concluded that the risk of ischemic stroke could be better evaluated if ECG were obtained and interpreted together with the information provided by ECHO.

One of the limitations of our study is that only a single observer made the diagnosis of LVH both in the echocardiographic study and in the ECG. In the first test, whose measurements are more observer-dependent, measurements taken by an examiner were compared with those taken by a second observer, and an interobserver agreement higher than 90% in the determination of LVM was verified\textsuperscript{39}. In relation to ECG, the measurements of the amplitude of the

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R and S waves in precordial leads were directly obtained from 20 recordings by two independent observers, and a high degree of reproducibility was observed (r=0.96), thus indicating a low probability of diagnostic errors using both criteria presented.

In conclusion, in our sample we found a superior performance in the Cornell criterion over the SLR criterion in the diagnosis of LVH for both genders. We suggest new gender-specific cut-off points for the Cornell criterion (2.1 mV and 1.9 mV) and for the SLR criterion (4.1 mV and 3.1 mV) for males and females, respectively. In populations where racial miscegenation with the black ethnic is significant, our findings show superiority of the Cornell criterion over the SLR criterion. However, further studies are necessary to define cut-off points for the race-stratified SLR criterion.

**Potential Conflict of Interest**

No potential conflict of interest relevant to this article was reported.

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**Study Association**

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**References**


3. Koren MJ, Devereux RB, Casale PN. Relation of left ventricular mass and geometry to morbidity and mortality in uncomplicated essential hypertension. Ann Intern Med. 1991; 114: 345-52.


