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# Left Ventricular Hypertrophy and Cardiovascular Disease Risk Prediction and Reclassification in Blacks and Whites: The ARIC Study

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## Abstract

Left Ventricular Hypertrophy (LVH) is a major independent predictor of cardiovascular disease (CVD) survival, and is more prevalent in blacks than whites. In a large biracial population, we evaluated the ability of ECG-determined LVH (ECG-LVH) to reclassify CVD/coronary heart disease (CHD) events beyond traditional risk factors in blacks and whites. The analysis included 14,489 participants (mean age 54+/−5.7 years, 43.5% men, 26% black) from the Atherosclerosis Risk in Communities (ARIC) cohort, with baseline (1987–989) ECG, followed for 10 years. Predicted risk for incident CVD and CHD were estimated using the 10-year Pooled Cohort and Framingham risk equations (base models 1a/1b), respectively. Models 2a and 2b included respective base model plus LVH by *any* of 10 traditional ECG-LVH criteria. Net reclassification improvement (NRI) was calculated, and the distribution of risk was compared using models 2a and 2b vs. models 1a and 1b, respectively. There were 792 (5.5%) 10-year Pooled Cohort CVD events, and 690 (4.8%) 10-year Framingham CHD events. LVH defined by any criteria was associated with CVD and CHD events [HR (95% CI): 1.62 (1.38–1.90) and 1.56 (1.32–1.86), respectively]. LVH did not significantly reclassify or improve C-statistic in models 2a/b [C-statistics: 0.767/0.719; NRI=0.001 (p=NS)], compared with the base models 1a/b (C-statistics: 0.770/0.718), respectively. No racial interactions were observed. In this large cohort of black and white participants, ECG-LVH was associated with CVD/CHD risk, but did not significantly improve CVD and CHD events risk prediction beyond the new Pooled Cohort and most utilized Framingham risk equations in blacks or whites.

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### Keywords

left ventricular hypertrophy; race; electrocardiography; risk prediction; coronary heart disease; cardiovascular disease; Pooled Cohort risk equation; Framingham risk equation

## Introduction

The Framingham risk equation which pioneered many of the methods commonly employed in risk estimation has shown good discrimination in a number of external validation studies,[1] but has some inadequacies cited in the literature.[1,2] These limitations have prompted the search for other non-traditional and more novel risk markers that could possibly improve risk prediction/assessment beyond the Framingham Risk Score (FRS). To this end, the American College of Cardiology (ACC) and American Heart Association (AHA) recently released the Pooled Cohort guidelines for estimation of 10-year risk for hard atherosclerotic CVD (ASCVD) using newly derived sex- and race-specific pooled cohort equations.[2]

Left ventricular hypertrophy (LVH), diagnosed using 12-lead electrocardiography (ECG), robustly predicts cardiovascular disease (CVD) events (including myocardial infarction [MI], sudden death, stroke, congestive heart failure and overall CVD mortality,[3,4] independent of traditional cardiovascular risk factors including hypertension, diabetes, smoking status and dyslipidemia.[3,5] LVH is more prevalent in African Americans with higher LV mass, is an independent predictor of coronary heart disease (CHD)/CVD survival beyond traditional risk factors,[6,7] and appears to be more important than multi-vessel coronary artery disease (CAD) and left ventricular systolic dysfunction in predicting survival in this population.[7] Furthermore, ECG-determined LVH (ECG-LVH) regression is associated with lower cardiovascular morbidity and mortality, as well as lower overall mortality, independent of blood pressure-lowering and treatment modality in patients with essential hypertension.[8] As such, LVH is possibly a major predictor of CVD, and likely a player in black-white differential in CVD survival.

LVH is a component of the Framingham Stroke equation, and although fatal and non-fatal strokes are 2 of 4 outcome measures of the ASCVD Pooled Cohort risk equations, and CHD appears to be the most important clinical associations of LVH,[4] LVH was not incorporated into the Pooled Cohort equations[2] or the Framingham CHD risk equation.[9] ARIC is a large cohort made up of black and white men and women. Using the various developed criteria for LVH diagnosis by ECG, we sought to evaluate the ability of ECG-LVH to predict/reclassify CVD outcomes beyond the newest (Pooled Cohort) risk equations in a large population of black and white men and women. In a secondary analysis, we also evaluated the ability of ECG-LVH to predict/reclassify CHD outcomes beyond the oldest and most utilized (Framingham) risk equation made up of traditional risk factors.

## Methods

### Study population

We used data from the Atherosclerosis Risk in Communities (ARIC) study which is a prospective, population-based cohort study designed to investigate the etiology and natural

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history of cardiovascular disease. From 1987 to 1989, 15,792 men and women aged 45–64 were enrolled from 4 U.S. communities: Jackson, MS; Washington County, MD; Forsyth County, NC; and suburbs of Minneapolis, MN. Details of the study design have been previously published.[10] The study was approved by institutional review boards at each participating center and all study participants provided written informed consent. We excluded the following: race other than white or black and non-whites in the Minneapolis and Washington County sites: n=103; Wolff-Parkinson-White (WPW), pacemaker, left bundle branch block or advanced degree heart block: n=13; prevalent CHD / CVD: n=763; missing readable ECG's: n=185; or missing covariates: n=239. Our final study population included 14,489 participants

## Electrocardiography

Patients underwent standard supine 12-lead ECG, with each tracing consisting of 10 seconds of each of the 12 leads simultaneously. ECG data processing, monitoring and quality control have been described elsewhere.[11] The amplitudes and durations of the ECG waveforms used in deriving the LVH criteria in this analysis were automatically measured using GE Marquette 12-SL version 2001 software (GE, Milwaukee WI). In addition to these measurements, all ECG were also classified by the Minnesota code at a single reading center.[12] ECG LVH was defined according to 10 previously defined criteria:[13] Sokolow-Lyon voltage (SV1 + RV5/V6 ≥3.5 mV and/or RaVL ≥1.1 mV); Gender-specific Cornell voltage (SV3 + RaVL >2.8 mV [for men] and >2.0 mV [for women]); Romhilt-Estes point score (partition values ≥5 points and ≥4 points); Framingham ECG-LVH criteria (presence of a strain pattern and at least 1 of the following voltage criteria: RI + SIII ≥2.5 mV, SV1/V2 + RV5/V6 ≥3.5 mV, the S wave on the right precordial lead ≥2.5 mV, and the R wave on the left precordial lead ≥2.5 mV); Perugia score (requires positivity of at least 1 of the following 3 criteria: SV3 + RaVL >2.4 mV [men] or >2.0 mV [women], left ventricular strain, or Romhilt-Estes score of ≥5); Lewis index ([RI + SIII] − [RIII + SI] >1.7 mV); Framingham-adjusted Cornell voltage - men: [RaVL + SV3 + 0.0174*(age – 49) + 0.191*(BMI − 26.5)] ≥2.8 mV; women: [RaVL + SV3 + 0.0387*(age – 50) + 0.212*(BMI − 24.9)] ≥2.0 mV); Cornell voltage product ([RaVL + SV3]*QRS duration ≥243,600 μVms); Sokolow-Lyon voltage product ([SV1 + RV5/RV6]*QRS duration ≥371,000 μVms); Gubner and Ungerleider voltage (RI + SIII ≥2.2 mV). For the current analysis, ECG-LVH status was determined at the baseline examination.

## Ascertainment of outcomes

Events were ascertained as previously described.[14] Deaths were investigated and ascertained by a review of death certificates, coroner records, and contact with physicians and patient families (when available). Prevalent coronary heart disease (CHD) was defined as prior cardiovascular revascularization, physician-diagnosed myocardial infarction, or presence of a previous myocardial infarction by ECG and incident CHD was ascertained and adjudicated by the ARIC Morbidity and Mortality Classification Committee using data from follow-up calls, hospitalization records and death certificates.[15] Outcomes of interest were incident CHD including fatal and non-fatal CHD. These were defined as a definite/probable MI, death from CHD, and/or resuscitated cardiac arrest. Hard ASCVD was defined as nonfatal definite/probable MI, death from CHD or stroke.[2]

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## Baseline measurements

Race, smoking and socio-economic status were determined by self-report during the baseline interview. Fasting plasma total cholesterol was measured by enzymatic methods. Resting sitting blood pressure was measured 3 times using a random-zero sphygmomanometer, and the average of the 2nd and 3rd measurements used for analysis. Use of antihypertensive medications within the past 2 weeks of baseline interview were self-reported or taken from prescription bottles. Diabetes was defined as: fasting glucose of 126 mg/dl or greater, random glucose of 200 mg/dl or greater, a self-reported physician diagnosis of diabetes, or pharmacological therapy for diabetes.

## Statistical Analysis

We estimated the association of baseline LVH by any criteria with the incidence of CVD during a 10 year follow-up using Cox proportional hazards models, with time to CVD as the main outcome variable. Risk estimates and reclassification for incident CVD during a 10-year follow-up were assessed using the 10-year Pooled Cohort risk equations,[2] Follow-up time was defined as time from baseline until death, the first CVD event or loss to follow-up, whichever came first. For Cox models and risk estimates with CVD, Model 1a was a base model using the Pooled Cohort Risk Model (age, gender, race, smoking (yes/no), diabetes (yes/no), systolic blood pressure, hypertension treatment, HDL cholesterol and total cholesterol) modeled as a risk score. Although race is a component of the score, the Pooled Cohort risk equations showed significant race interactions. As such, we added an interaction term into our model for overall analysis. Model 2a included the base models plus LVH by any of 10 traditional ECG-LVH criteria.[16]

To determine improvement in model discrimination with addition of each LVH criteria, we calculated the Harrell's C-statistic for CVD and CHD risk using methods which accounted for censoring[17] for the base model and the base model plus LVH criteria (expanded model). Bootstrapping was performed to conduct an internal validation of the expanded model.[18] To evaluate reclassification, we calculated the category-based net reclassification improvement (NRI), taking into account censored observations.[16] Using Cox proportional hazards, the CVD/CHD risk was calculated, and individuals were classified into <10%, 10–20%, and >20% risk categories based on ATP-III population risk definitions.[19] We compared the distribution of risk using models 2 vs. models 1. In addition, we estimated the integrated discrimination improvement (IDI) which is the sum of the difference in discrimination slopes of the 2 models.[20]

In supplemental data, similar analyses were carried out using the Framingham risk equation for the evaluation of LVH in CHD risk prediction and reclassification. The interactions between race and LVH and sex and LVH were tested. All statistical analyses were performed with SAS v 9.2 (SAS Inc, Cary, NC).

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## Results

Our study included 14,489 ARIC participants, 6303 (43.5%) were men and 3767 (26%) black (Table 1). At baseline, 2833 (19.6%) had LVH by any of our 10 defined criteria. The highest prevalence of LVH was observed with the Lewis index (10.5%), while the lowest prevalence of 1.6% was observed using the Framingham ECG score (Table 2). LVH was more prevalent in blacks compared with whites, regardless of the criteria used in its definition. We assessed CVD in our study using the Pooled Cohort equation, and assessed CHD with the Framingham risk equation (supplemental data). Based on the Pooled Cohort ASCVD risk categories, the prevalence of ECG-LVH was 891 (12.3%), 464 (21.3%) and 1478 (29.1%) in the categories with < 5%, 5–7.5%, and ≥ 7.5% 10-year risk of CVD events, respectively.

Overall, there were 792 (5.5%) 10 year ASCVD events (201 strokes, 486 with MI, and 105 with a fatal CHD event): 541 in whites (5.0%), 251 in blacks (6.7%). The median follow-up time was 10 years (mean of 9.5 years). The total amount of person-years of follow-up was 137,576. The cumulative incidence rate (95% CI) for CVD events in 10 years of follow-up were 5.76 (5.37–6.17) and 5.02 (4.65–5.40) respectively, per 1000 person-years in the entire cohort

### Reclassification of CVD and CHD by LVH Criteria

None of the individual LVH criterion showed statistically significant improvement in C-statistic or NRI beyond the base model 1a made up of the Pooled Cohort risk factor variables for CVD assessment (Table 3a). Similarly, model 2a which defined LVH by *any* of the criteria did not improve the NRI or C-statistic [C-statistic (95% CI): 0.767 (0.751–0.782), beyond the base model 1a [C-statistic 0.770 (0.755–0.785)]. The IDI was statistically significant for Sokolow-Lyon voltage, Framingham ECG score and presence of LVH by *any* criteria. When broken down by race, neither of the individual LVH criterion, nor LVH defined by any criteria improved C-statistic significantly beyond the base model 1a (Table 3b). The IDI for CVD was statistically significant for LVH by *any* criteria in whites, but not blacks. There were no sex or race interactions observed.

Our overall findings were unchanged when the Pooled Cohort equations base model 1a was replaced with the Framingham risk equation base model 1b – where model 2b included base model 1a made of the Framingham risk equation *plus* LVH – for assessment of CHD risk prediction (Suppl. Tables 1a and 1b).

### Multivariate Analysis for Associations between LVH Criteria and CHD

The presence of LVH (defined by any criteria) was significantly associated with incident CVD and CHD overall, and in either of the racial groups (all $p < 0.01$); Suppl. Tables 2 and

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3. The Framingham ECG score was most associated with CVD in blacks and whites, and with CHD in blacks; while the Cornell voltage product was most associated with CHD in whites.

## Discussion

To our knowledge, this is the first study to show that independent of black/white race, the presence of LVH by any or all of the LVH-ECG criteria did not significantly reclassify CVD events risk by NRI, and did not show significant improvement in CVD events risk prediction by C-statistic, beyond the Pooled Cohort equation made up of traditional cardiovascular risk factors. In supplemental data, our findings were similar when we evaluated the ability of LVH to predict/reclassify CHD risk beyond the Framingham risk equation. Similar to other LVH studies,[6,21] our study showed LVH to have significant independent associations with CVD beyond traditional risk factors in both blacks and whites.

The Pooled Cohort equations were designed to overcome some of the limitations of the FRS which include: its focus on 10-year rather than lifetime risk assessment, the strong contribution of age (a non-modifiable risk factor), limited ethnic diversity, narrow endpoint of CHD risk (thus missing out prediction of ischemic stroke).[1,2] As such, the Pooled Cohort equations are based on cohorts broadly representative of the US population that included participants from ARIC, Coronary Artery Risk Development in Young Adults (CARDIA) study, Cardiovascular Health (CHS) study; in addition to applicable data from the Framingham Original and Offspring Study cohorts.[2] To this end, the pool represents black and white men and women aged 40 – 79 years, and have focused on determining the need for medical therapy for primary or secondary prevention of CVD based on presence/absence of disease, diabetes, high cholesterol and patient's level of risk.

Electrocardiography-diagnosed LVH – with a large effect on CHD and CVD risk prediction – has been incorporated in the Framingham risk model for stroke;[14,15,39] and fatal and non-fatal strokes are 2 of 4 outcome measures of the Pooled Cohort risk equations.[2] Furthermore, LVH is an important and independent predictor of cardiac events,[3–5,21] and is more prevalent and severe in blacks than whites.[13,22] One would therefore expect – contrary to our study findings – that LVH would reclassify CVD risk beyond the Pooled Cohort/ Framingham risk equations particularly in blacks, given that blacks are also more prone to adverse events from CVD. Our study is a unique and an important addition to the literature in that it has examined this possibility for CVD and CHD, incorporating the latest, as well as the oldest/most prevalently utilized risk equations for cardiovascular risk estimation.

In further analysis, we found that LVH significantly increased C-statistic by 1.1%, over a base model made up of age, sex and race. While this makes LVH prognostically relevant in CHD/CVD risk assessment, this observed increase in C-statistic was lower than that seen with each of the individual traditional cardiovascular risk factors added to the base model. Taken together, our study data suggest that traditional cardiovascular risk factors are more fundamental than LVH – a downstream effect of these risk factors – in the prediction of CHD/CVD, and is a very likely explanation for lack of predictive/reclassification utility of

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LVH in our study. In particular, hypertension, a major variable in the assessment of CVD and CHD, has co-linearity with LVH.

### Study Limitations

One limitation of our study is that we employed ECG in the diagnosis of LVH for our study. It is noteworthy that ECG-LVH provided the first insight into worsened prognosis of LVH, including heart failure, sudden death and unrecognized myocardial infarction.[24] While echocardiography is the most commonly employed modality for detection of LVH, cardiac magnetic resonance imaging (MRI) is the current standard of reference for accurate and reproducible assessment of left ventricular mass.[25] Combined, the various ECG criteria for diagnosis of LVH have shown low sensitivity, but high specificity (> 99%) for diagnosis of MRI-defined LVH.[13] This means that ECG-LVH has significant ability to rule in MRI-defined LVH, but should not impact our study findings since high specificity implies that those diagnosed with LVH by ECG likely had true LVH if assessed by MRI, and were included in our study. In addition, ECG – unlike MRI – is a readily accessible and inexpensive screening tool which appropriately served the purpose of our study in the search for easily obtainable risk factor(s) that accurately predict CHD events in a population.

Another limitation of our study is the relatively long follow-up period after each ECG had been performed. There were no interval ECGs performed to monitor changes in LVH and disease process in this study. Individual blood pressures could also have been different or fluctuating over time, and this could have affected our findings.

### Conclusion

We found that in both black and white participants, despite its significant associations with CVD/CHD risk, LVH (determined by any individual or all of the LVH ECG criteria) did not significantly add to reclassification or prediction of CVD or CHD events beyond the Pooled Cohort and Framingham risk equations made up of traditional cardiovascular risk factors. No major differences between black and white participants were observed.

### Perspectives

To our knowledge, this is the first study that examines whether LVH would improve CVD or CHD risk prediction beyond traditional cardiovascular risk factors (particularly in blacks). Our study was also unique in its approach of using the newest Pooled Cohort risk model for CVD, and the most widely utilized Framingham risk model for CHD in carrying out the analysis for risk prediction and reclassification. Our study corroborates the pivotal role of the traditional components of the Pooled Cohort and Framingham risk equations in the prediction of CVD and CHD, respectively. It also suggests the presence of other contributors, different from LVH, to black-white disparities in CVD and CHD prevalence and incidence. Findings from our study suggest that data sets can be risk adjusted without the time and barrier of including ECG-LVH data.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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## Novelty and Significance

**What is New**

- To our knowledge, this is the first study that has the ability of left ventricular hypertrophy to predict risk of cardiovascular disease events beyond the newest, as well as the oldest (and most utilized) risk prediction tools
- The findings of our study – that left ventricular hypertrophy does not add predictive value and does not improve reclassification of cardiovascular events beyond traditional cardiovascular risk factors in both African Americans and white populations, or in African Americans compared with their white counterparts
- Our study suggests that left ventricular hypertrophy is not one of the major contributors to black-white disparities in cardiovascular outcome

**What is Relevant**

- Hypertension is more prevalent in blacks, and is one of the major risk factors that lead to left ventricular hypertrophy
- Cardiovascular mortality remains higher in blacks relative to whites
- Control of hypertension has been associated with regression of left ventricular hypertrophy
- Changes in left ventricular geometry, including left ventricular hypertrophy, is one of the ways in which hypertension leads to increased cardiovascular morbidity and mortality

**Summary**

Left ventricular hypertrophy – diagnosed by ECG – is one of the major contributors to cardiovascular disease risk but does not add significantly to risk assessment beyond the traditional cardiovascular risk factors

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## Table 1

Baseline Characteristics According to Presence or Absence of Left Ventricular Hypertrophy by any Definition, ARIC, 1987–1989

| | Total population (n=14489) | No LVH (n=11656) | LVH (n=2833) | p-value |
|---|---|---|---|---|
| **Age** | 54.0 (5.7) | 53.8 (5.7) | 54.8 (5.7) | <0.0001 |
| **Sex (% Men)** | 43.5 | 41.8 | 50.4 | <0.0001 |
| **Race (% Black)** | 26.0 | 19.8 | 51.5 | <0.0001 |
| **Current cigarette Smoking (%)** | 26.0 | 26.9 | 22.2 | <0.0001 |
| **Diabetes (%)** | 11.1 | 9.4 | 18.0 | <0.0001 |
| **Antihypertensive medications (%)** | 28.4 | 24.2 | 45.6 | <0.0001 |
| **Systolic blood pressure, mmHg** | 121.1 (18.7) | 118.5 (16.9) | 131.8 (21.8) | <0.0001 |
| **HDL cholesterol, mmol/L** | 1.3 (0.4) | 1.4 (0.4) | 1.3 (0.4) | <0.0001 |
| **Total cholesterol, mmol/L** | 5.5 (1.1) | 5.5 (1.1) | 5.6 (1.1) | 0.0002 |

* All values are mean (standard deviation) unless otherwise noted

† Chi-square test of association for percentages, T-test for means

‡ Abbreviations: LVH = left ventricular hypertrophy

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## Table 2

Prevalence of Left Ventricular Hypertrophy by Separate Definitions, ARIC, 1987–1989

| LVH Criteria | Total Population N (%) | By Race | |
|---|---|---|---|
| | | White, N (%) | Black, N (%) |
| **Sokolow-Lyon voltage** | 1392 (9.6) | 515 (4.8) | 877 (23.3) |
| **Gender-specific Cornell voltage** | 297 (2.1) | 97 (0.9) | 200 (5.3) |
| **Romhilt-Estes point score** | 311 (2.2) | 157 (1.5) | 154 (4.1) |
| **Framingham ECG score** | 232 (1.6) | 91 (0.9) | 141 (3.8) |
| **Perugia score** | 1209 (8.3) | 545 (5.1) | 664 (17.7) |
| **Lewis index** | 1514 (10.5) | 745 (7.0) | 769 (20.4) |
| **Framingham-adjusted Cornell voltage** | 501 (3.5) | 174 (1.6) | 327 (8.7) |
| **Cornell voltage product** | 510 (3.5) | 237 (2.2) | 273 (7.3) |
| **Sokolow-Lyon voltage product** | 509 (3.5) | 165 (1.5) | 344 (9.1) |
| **Gubner and Ungerleider voltage** | 775 (5.4) | 325 (3.0) | 450 (12.0) |
| **Any of the above LVH criteria** | 2833 (19.6) | 1374 (12.8) | 1459 (38.8) |

* Abbreviations: LVH = left ventricular hypertrophy

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## Table 3

**a. Reclassification of Cardiovascular Disease by the Addition of each Criterion for Left Ventricular Hypertrophy, Based on a 10-year Pooled Cohort Risk Model, ARIC 1987–1989**

| | C-statistic (95% CI) | NRI, categorical (95% CI) | IDI (p-value) |
|---|---|---|---|
| **Base model 1a*** | 0.770 (0.755–0.785) | | |
| **Sokolow-Lyon voltage** | 0.770 (0.755–0.785) | 0.001 (−0.013 to 0.014) | 0.001 (p=0.03) |
| **Gender-specific Cornell voltage** | 0.770 (0.755–0.786) | −0.006 (−0.015 to 0.003) | 0.001 (p=0.09) |
| **Romhilt-Estes point score** | 0.769 (0.753–0.784) | −0.007 (−0.016 to 0.001) | 0.001 (p=0.09) |
| **Framingham ECG score** | 0.772 (0.757–0.787) | 0.004 (−0.008 to 0.016) | 0.002 (p=0.02) |
| **Perugia score** | 0.770 (0.755–0.785) | −0.008 (−0.023 to 0.007) | 0.001 (p=0.10) |
| **Lewis index** | 0.769 (0.754–0.785) | −0.002 (−0.008 to 0.005) | 0.0003 (p=0.14) |
| **Framingham-adjusted Cornell voltage** | 0.770 (0.755–0.785) | −0.002 (−0.012 to 0.009) | 0.0009 (p=0.08) |
| **Cornell voltage product** | 0.770 (0.755–0.786) | −0.007 (−0.018 to 0.002) | 0.0009 (p=0.13) |
| **Sokolow-Lyon voltage product** | 0.769 (0.754–0.784) | −0.004 (−0.014 to 0.006) | 0.0006 (p=0.23) |
| **Gubner and Ungerleider voltage** | 0.769 (0.754–0.785) | −0.0006 (−0.008 to 0.006 | 0.0002 (p=0.34) |
| **Presence of any LVH criteria** | 0.767 (0.751–0.782) | −0.006 (−0.021 to 0.007) | 0.002 (p=0.004) |

**b. Reclassification of Cardiovascular Disease by the Addition of each Left Ventricular Hypertrophy Criteria by Race, Based on a 10-year Pooled Cohort Risk Model, ARIC 1987–1989**

| | C-statistic (95% CI) | NRI | IDI |
|---|---|---|---|
| **Whites (n=10,727):** | | | |
| **Base model 1a*** | 0.773 (0.755–0.791) | | |
| **Sokolow-Lyon voltage** | 0.771 (0.753–0.789) | 0.004 (p=0.46) | 0.001 (p=0.03) |
| **Gender-specific Cornell voltage** | 0.773 (0.755–0.791) | −0.002 (p=0.35) | 0.0001 (p=0.45) |
| **Romhilt-Estes point score** | 0.772 (0.754–0.790) | −0.0004 (p=0.88) | 0.00009 (p=0.56) |
| **Framingham ECG score** | 0.774 (0.756–0.792) | −0.0004 (p=0.95) | 0.0005 (p=0.28) |
| **Perguia score** | 0.772 (0.754–0.790) | −0.005 (p=0.49) | 0.001 (p=0.06) |
| **Lewis index** | 0.771 (0.753–0.789) | 0.001 (p=0.75) | 0.0007 (p=0.05) |
| **Framingham-adjusted Cornell voltage** | 0.773 (0.755–0.791) | −0.002 (p=0.59) | 0.0004 (p=0.28) |
| **Cornell voltage product** | 0.773 (0.755–0.791) | −0.002 (p=0.45) | 0.0001 (p=0.59) |
| **Sokolow-Lyon voltage product** | 0.771 (0.753–0.789) | 0.002 (p=0.52) | 0.0004 (p=0.12) |
| **Gubner and Ungerleider voltage** | 0.772 (0.754–0.790) | 0.001 (p=0.44) | 0.0001 (p=0.22) |
| **Any LVH criteria** | 0.768 (0.750–0.786) | −0.002 (p=0.76) | 0.002 (p=0.008) |
| **Blacks (n=3762):** | | | |
| **Base model 1a*** | 0.774 (0.747–0.800) | | |
| **Sokolow-Lyon voltage** | 0.772 (0.744–0.799) | −0.025 (p=0.15) | 0.002 (p=0.27) |
| **Gender-specific Cornell voltage** | 0.774 (0.748–0.800) | −0.020 (p=0.15) | 0.004 (p=0.12) |
| **Romhilt-Estes point score** | 0.773 (0.746–0.800) | −0.018 (p=0.17) | 0.004 (p=0.12) |
| **Framingham ECG score** | 0.777 (0.751–0.804) | 0.0006 (p=0.97) | 0.007 (p=0.03) |
| **Perguia score** | 0.769 (0.742–0.796) | −0.026 (p=0.13) | 0.010 (p=0.55) |

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**b. Reclassification of Cardiovascular Disease by the Addition of each Left Ventricular Hypertrophy Criteria by Race, Based on a 10-year Pooled Cohort Risk Model, ARIC 1987–1989**

| | C-statistic (95% CI) | NRI | IDI |
|---|---|---|---|
| **Lewis index** | 0.774 (0.747–0.800) | −0.005 (p=0.26) | 0.0001 (p=0.71) |
| **Framingham-adjusted Cornell voltage** | 0.777 (0.748–0.806) | −0.012 (p=0.43) | 0.003 (p=0.18) |
| **Cornell voltage product** | 0.773 (0.747–0.800) | −0.025 (p=0.07) | 0.003 (p=0.15) |
| **Sokolow-Lyon voltage product** | 0.772 (0.745–0.799) | −0.017 (p=0.20) | 0.0009 (p=0.55) |
| **Gubner and Ungerleider voltage** | 0.773 (0.747–0.799) | −0.009 (p=0.26) | 0.0001 (p=0.79) |
| **Any LVH criteria** | 0.765 (0.736–0.793) | −0.023 (p=0.10) | 0.002 (p=0.18) |

* Covariates in the base model 1a are the Pooled Cohort risk equations (age, gender, race, smoking (yes/no), diabetes (yes/no), systolic blood pressure, hypertension treatment, HDL cholesterol, and total cholesterol), race, and a race*score interaction term.

† NRI categorized as <10%, 10–20% and >20%

‡ Abbreviations: NRI = Net Reclassification Index, IDI = Integrated Discrimination Index, HR = Hazard Ratio, CI = Confidence Interval, LVH = left ventricular hypertrophy