Left-Ventricular Structure in the Southall And Brent REvisited (SABRE) Study
Explaining Ethnic Differences

Chloe M. Park, Katherine March, Arjun K. Ghosh, Siana Jones, Emma Coady, Claire Tuson, Darrel Francis, Jamil Mayet, Therese Tillin, Nish Chaturvedi, Alun D. Hughes

Abstract—Cardiometabolic risk is elevated in South Asians and African Caribbeans compared with Europeans, yet whether this is associated with ethnic differences in left-ventricular structure is unclear. Conventional M-mode or 2-dimensional echocardiography may be misleading, because they calculate left-ventricular mass and remodeling using geometric assumptions. Left-ventricular structure was compared in a triethnic population-based cohort using conventional and 3-dimensional echocardiography on 895 individuals (aged 55–85 years; 427 European, 325 South Asian, 143 African Caribbean). Left-ventricular mass was indexed, and left-ventricle remodeling index and relative wall thickness were calculated. Anthropometry, blood pressure, and fasting bloods were measured. Three-dimensional left-ventricular mass index did not differ between Europeans (mean±SE, 29.8±0.3 g/m²) and African Caribbeans (29.9±0.5 g/m²; P=0.9), but it was significantly lower in South Asians (28.1±0.4 g/m²; P<0.0001) compared with Europeans. These findings persisted on multivariate adjustment. In contrast, conventional left-ventricle mass index was significantly higher in African Caribbeans (46.4±0.9 g/m²) than in Europeans (41.9±0.5 g/m²; P<0.0001). Left-ventricle remodeling index was the highest in African Caribbeans and the lowest in South Asians. Relative wall thickness was also higher in African Caribbeans, but no different in South Asians, compared with Europeans. Differences in left-ventricular remodeling index were attenuated by adjustment for cardiometabolic factors between African Caribbeans and Europeans only. In conclusion, left-ventricular mass is lower in South Asians and equivalent in African Caribbeans compared with Europeans, even when cardiometabolic risk factors are accounted for. Left-ventricular remodeling rather than hypertrophy may explain the increased risk of heart failure in people of African Caribbean origin. (Hypertension. 2013;61:1014-1020.) • Online Data Supplement

Key Words: cardiometabolic disease ■ conventional echocardiography ■ ethnicity ■ left-ventricular mass ■ left-ventricular remodeling ■ three-dimensional echocardiography

Increased left-ventricular (LV) mass and LV hypertrophy (LVH) predict cardiovascular disease (CVD), independently of other risk factors,1,2 and are important risk factors for heart failure (HF).3 There are marked differences in CVD in ethnic groups resident in the United Kingdom;4 South Asian (ie, originating from the Indian subcontinent) people have excess risks of coronary heart disease (CHD), whereas people of African Caribbean origins have lower rates of CHD compared with Europeans. Both ethnic minority groups have greater stroke rates than comparator European populations,5–7 greater rates of diabetes mellitus, and greater risk of HF.8–10

Although people of Black African descent in the United Kingdom and United States are reported to have higher LV mass and prevalence of LVH compared with European origin populations,11–13 the sole study of healthy South Asian volunteers reported lower LV mass but higher relative wall thickness (RWT),8 however participants with any evidence of CVD, including calcification scores >10 agaston units, were excluded from this study. Previous studies often excluded individuals with known CVD or risk factors, however because these differ considerably by ethnicity, this may result in a biased and ungeneralizable sample. A further limitation common to these previous studies is that they have used M-mode and 2-dimensional (2D) echocardiography to assess LV structure. This approach is based on geometric assumptions that may not be valid,14 particularly in different ethnic groups. Furthermore, whether known ethnic differences in cardiometabolic risk can account for any differences in LV structure has not been fully explored, although such analysis may provide valuable insights into pathological pathways.

Therefore, we measured LV structure using real-time 3-dimensional (3D) echocardiography in a population-based
sample of European, South Asian, and African Caribbean individuals in the United Kingdom, compared findings with conventional echocardiography, and investigated the role of cardiometabolic factors in accounting for any ethnic differences observed.

Methods

Study Population

The SABRE (Southall And Brent REvisited) study is a triennial population-based cohort consisting of white European (2346), first generation migrant South Asian (1711), and African Caribbean (801) men and women. Details of the cohort have been published; in brief, participants, aged 40 to 69 years, were recruited from primary care and baseline measurements performed between 1988 and 1991. Surviving participants were invited to attend the 20-year follow-up investigation between 2008 and 2011. Echocardiography was not available for the initial part of the follow-up, of the 1402 participants (661 Europeans; 510 South Asians; and 231 African Caribbeans) that attended during the time that functional echocardiography was available, a total of 1356 (642 Europeans; 490 South Asians; and 224 African Caribbeans) participants agreed to undergo echocardiographic examination. The study was approved by the local research ethics review committee, and all subjects gave written informed consent. This study adheres to the principles of the Declaration of Helsinki and Title 45, US Code of Federal Regulations, part 46. Protection of Human Subjects. Revised November 13, 2001, effective December 13, 2001, and all the procedures followed were in accordance with institutional guidelines.

Investigations

Participants fasted and refrained from alcohol, smoking, and caffeine for ≥12 hours before attendance and omitted any medication on the morning of investigation. A questionnaire was completed, which detailed health behaviors, medical history, and medication. Height, weight, and waist circumference were measured as previously described. CHD was defined as a coronary event or revascularization identified by medical record review and adjudicated by an independent committee. Seated brachial blood pressure was measured after 10 minutes rest using an automatic Omron 705IT. An appropriate sized cuff was placed on to the left upper arm, 3 recordings were taken 2 minutes apart, and the second and third recordings were averaged. Fasting blood samples were taken for glucose, insulin, glycated hemoglobin (HbA1c), and lipid profiles, and the homeostasis model assessment of insulin resistance (HOMA-IR) was calculated.

3D Echocardiography

Real-time 3D echocardiography was performed by 2 experienced cardiovascular physiologists using a Philips iE33 ultrasound machine. Three-dimensional full volume sets were acquired from the apical 4-chamber view with a matrix array transducer (X3). Data sets were acquired over 4 cardiac cycles during held respiration in the wide-angled acquisition mode (93°×80°). Offline, the endocardial and epicardial boundaries of nonforeshortened 2- and 4-chamber LV views were traced using Philips Qlab 7.0, and 3D LV mass was calculated using the biplane method of discs. Three-dimensional end diastolic/systolic volume, ejection fraction, stroke volume, cardiac output, total peripheral resistance, total arterial compliance, and LV remodeling index (LVRI) were calculated (see the online-only Data Supplement).

M-Mode and 2D Echocardiography

M-mode and 2D echocardiography were performed using a 5.0-1.0 phased array transducer (S5-1). LV mass and RWT by conventional echocardiography were calculated according to American Society of Echocardiography (ASE) guidelines from 2D guided M-mode. LV Indexing and Remodeling

To account for differences in body size, LV mass was indexed to body surface area (LVMi) calculated using the Dubois formula. LVH using 3D data was defined using the Multi-Ethnic Study of Atherosclerosis (MESA) upper 95th percentile values that were calculated from a reference sample of healthy participants, which contained participants from all MESA ethnic groups, as described by Brumback et al. LVH based on conventional echocardiography was classified according to ASE guidelines, and LV remodeling was further categorized into normal, concentric remodeling, concentric hypertrophy, and eccentric hypertrophy patterns as proposed by Lang et al, on the basis of RWT and LV mass indexed to body surface area.

Reproducibility

To assess the intra- and interobserver reproducibility of conventional LV mass and 3D LV mass, 10 participants were selected at random and studied on 2 separate occasions by both sonographers. Reproducibility is presented as mean difference±SD of difference and the intraclass correlation coefficient (ICC) within and between observers. For 3D LV mass, the within-observer difference was −5.0±7.0 g (ICC=0.92), and the between-observers difference was 2.3±7.4 g (ICC=0.92). For conventional LV mass, the within-observer difference was 0.3±14.9 g (ICC=0.94), and the between-observers difference was 2.9±14.7 g (ICC=0.93).

Statistical Analysis

For the 3D analysis, the study was powered to detect a standardized difference in LVMi of 0.30 in African Caribbeans versus Europeans and ≥0.20 in South Asians versus Europeans with 80% power and 5% significance. Previous studies have reported differences as large or larger than this. Data are reported as mean±SD or median (interquartile range) for skewed data unless stated otherwise. Statistical analyses were performed using Stata 12.0 (Stat Corp., TX). Comparisons of ethnic groups were made using ANOVA followed by post hoc testing if ANOVA was significant. Skewed data were natural log transformed before analysis. To explore explanations for ethnic differences in LV structure, multivariate analysis was performed. Covariates (age, sex, systolic blood pressure, blood pressure-lowering medication, heart rate, diabetes mellitus, log fasting HbA1c, log fasting insulin, weight, total arterial compliance, HDL fasting cholesterol, and CHD) were included in models a priori based on their known influence on LV structure. Possible interactions by sex were sought, but in the absence of any sex interaction, data from both sexes were pooled, with adjustment for sex in all multivariate models. For related variables (eg, fasting glucose, HbA1c, diabetes mellitus), the single variable that best attenuated the ethnic difference was retained for the final model. A P value of <0.05 was considered statistically significant.

Results

Participants who attended the 20-year follow-up clinic were, at baseline (1988–1990), younger and tended to be healthier than nonattendees, these differences applied to all ethnic groups with no significant difference by ethnicity (Table S1 in the online-only Data Supplement). The mean age of clinic attendees was 69.6±6.2 years. South Asians and African Caribbeans were more likely to have hypertension and diabetes mellitus than Europeans (Table 1). South Asian men and women had significantly more CHD compared with Europeans, however African Caribbean men had significantly less. In addition, South Asian men and women were shorter, lighter, but more centrally obese, and African Caribbean women were heavier and more centrally obese than their European counterparts. Conventional echocardiography was analyzable in 96% of clinic attendees, and adequate 3D echocardiography data were obtained in 65%; this proportion did not differ by ethnicity. Comparisons of 3D and conventional echocardiography are made only on those participants where...
both sets of measurements are available. People in whom LV mass could not be measured by 3D echocardiography were heavier and were more likely to have diabetes mellitus (Table S2). There were no ethnic differences in those in whom we did and did not have 3D echocardiography data (P=0.07 for weight and P=0.7 for diabetes mellitus).

### 3D Echocardiography

African Caribbeans had similar 3D LVMI<sup>2.7</sup>/LVMI to Europeans, but lower end diastolic volume, so that calculated concentricity (LVRI) was higher in African Caribbeans. Compared with Europeans, 3D LV mass, LVMI<sup>2.7</sup>/LVMI, and end diastolic volume were lower in South Asians (Table 2). Indexing end diastolic volume attenuated this difference, and LVRI was significantly smaller in South Asians.

### Conventional Echocardiography

In contrast to the findings with 3D echocardiography, LVMI<sup>2.7</sup>/LVMI by conventional echocardiography was significantly greater in African Caribbeans than in Europeans. Interventricular septum at end diastole, posterior wall thickness at end diastole, and RWT were greater (Table 3). LVMI<sup>2.7</sup>/LVMI and left-ventricular internal dimension at end diastole were lower in South Asians than in Europeans (Table 3), although RWT was similar. Conventional echocardiography generated higher values of LVMI<sup>2.7</sup> and LVMI than 3D echocardiography. This difference was more marked for African Caribbeans than the other 2 ethnic groups (Figure S1). For all those with 2D echocardiography, regardless of availability of 3D, LVMI<sup>2.7</sup> was 2.1±0.1 g/m<sup>2.7</sup> lower in South Asians (P=0.004) and 3.4±0.1 g/m<sup>2.7</sup> higher in African Caribbeans (P<0.0001) compared with Europeans, reflecting findings reported in the subset with both 3D and conventional echocardiography reported in Table 3.

### Comparison of Conventional and 3D Echocardiography for Determining LVH and Ethnic Differences

Using 3D echocardiography, African Caribbeans were least likely to have normal LV geometry (Figure S2; P<0.0001). Concentric remodeling was the most common pattern in all ethnic groups with African Caribbeans having the highest prevalence (81.1% compared with 63.8% in Europeans and 64.4% in South Asians, P<0.0001). Both concentric and eccentric hypertrophy were relatively uncommon, with no ethnic differences.

### Table 1. Characteristics by Sex and Ethnicity of Individuals That Had Three-Dimensional and Two-Dimensional Echocardiography

<table>
<thead>
<tr>
<th>Variables</th>
<th>European (n=332)</th>
<th>South Asian (n=285)</th>
<th>African Caribbean (n=86)</th>
<th>P Value (ANOVA)</th>
<th>European (n=95)</th>
<th>South Asian (n=40)</th>
<th>African Caribbean (n=57)</th>
<th>P Value (ANOVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>70.1±6.2</td>
<td>69.2±6.0</td>
<td>70.9±5.8</td>
<td>0.05</td>
<td>68.9±6.5</td>
<td>68.8±7.0</td>
<td>69.6±6.4</td>
<td>0.8</td>
</tr>
<tr>
<td>Height, m</td>
<td>1.73±0.07</td>
<td>1.69±0.06*</td>
<td>1.72±0.06</td>
<td>&lt;0.0001</td>
<td>1.60±0.06</td>
<td>1.55±0.05*</td>
<td>1.59±0.05</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>80.4±11.7</td>
<td>71.7±9.5</td>
<td>79.3±11.3</td>
<td>&lt;0.0001</td>
<td>67.0±12.0</td>
<td>63.2±11.5</td>
<td>71.6±11.3</td>
<td>0.002</td>
</tr>
<tr>
<td>Waist-hip ratio</td>
<td>0.98±0.06</td>
<td>1.0±0.05*</td>
<td>0.99±0.07</td>
<td>0.0001</td>
<td>0.88±0.07</td>
<td>0.95±0.09*</td>
<td>0.91±0.07</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>SBP, mmHg</td>
<td>140±18</td>
<td>142±18</td>
<td>144±16</td>
<td>0.1</td>
<td>134±18</td>
<td>139±18</td>
<td>139±17</td>
<td>0.2</td>
</tr>
<tr>
<td>DBP, mmHg</td>
<td>78±10</td>
<td>77±10</td>
<td>80±10</td>
<td>0.02</td>
<td>73±8</td>
<td>73±9</td>
<td>75±8</td>
<td>0.3</td>
</tr>
<tr>
<td>Heart rate, bpm</td>
<td>68±12</td>
<td>66±12*</td>
<td>65±11</td>
<td>0.005</td>
<td>70±10</td>
<td>71±11</td>
<td>65±11</td>
<td>0.003</td>
</tr>
<tr>
<td>Treated hypertension, n (%)</td>
<td>166 (50)</td>
<td>219 (77)*</td>
<td>59 (69)*</td>
<td>&lt;0.0001</td>
<td>37 (39)</td>
<td>23 (58)*</td>
<td>44 (77)*</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Total cholesterol, mmol/L</td>
<td>4.8±1.1</td>
<td>4.4±1.0*</td>
<td>4.6±1.1</td>
<td>&lt;0.0001</td>
<td>5.5±1.0</td>
<td>5.2±1.3</td>
<td>4.9±1.2</td>
<td>0.005</td>
</tr>
<tr>
<td>HDL cholesterol, mmol/L</td>
<td>1.4±0.3</td>
<td>1.3±0.3*</td>
<td>1.4±0.4</td>
<td>0.0005</td>
<td>1.6±0.4</td>
<td>1.5±0.3</td>
<td>1.6±0.3</td>
<td>0.5</td>
</tr>
<tr>
<td>Triglycerides mmol/L</td>
<td>1.13 (0.9–1.5)</td>
<td>1.17 (0.9–1.6)</td>
<td>0.83 (0.7–1.1)*</td>
<td>&lt;0.0001</td>
<td>1.14 (0.8–1.5)</td>
<td>1.22 (0.9–1.7)*</td>
<td>0.80 (0.6–1.1)*</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>LDL cholesterol, mmol/L</td>
<td>2.9±1.0</td>
<td>2.6±0.9*</td>
<td>2.8±0.9*</td>
<td>&lt;0.0001</td>
<td>3.4±0.9</td>
<td>3.1±1.1</td>
<td>2.9±1.0*</td>
<td>0.02</td>
</tr>
<tr>
<td>Glucose, mmol/L</td>
<td>5.1 (4.8–5.6)</td>
<td>5.3 (4.8–6.0)*</td>
<td>5.1 (4.8–5.7)</td>
<td>0.02</td>
<td>4.9 (4.7–5.2)</td>
<td>5.0 (4.5–5.9)</td>
<td>5.1 (4.7–5.5)</td>
<td>0.7</td>
</tr>
<tr>
<td>HbA₁&lt;sub&gt;C&lt;/sub&gt;, %</td>
<td>5.5 (5.3–5.7)</td>
<td>5.8 (5.5–6.0)*</td>
<td>5.8 (5.4–6.0)*</td>
<td>&lt;0.0001</td>
<td>5.2 (5.1–5.4)</td>
<td>5.7 (5.4–5.9)</td>
<td>5.4 (5.3–5.6)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Insulin, pmol/L</td>
<td>8.4 (5.4–12.4)</td>
<td>9.06 (6.0–14.0)</td>
<td>7.7 (7.4–11.1)</td>
<td>0.15</td>
<td>6.83 (4.5–9.6)</td>
<td>8.2 (6.0–12.1)</td>
<td>7.11 (4.9–9.9)</td>
<td>0.2</td>
</tr>
<tr>
<td>HOMA-IR</td>
<td>1.3±0.8</td>
<td>1.4±1.1</td>
<td>1.1±0.8</td>
<td>0.04</td>
<td>1.1±0.8</td>
<td>1.3±0.8</td>
<td>1.1±0.8</td>
<td>0.3</td>
</tr>
<tr>
<td>Diabetes mellitus, n (%)</td>
<td>53 (16)</td>
<td>112 (40)*</td>
<td>32 (37)*</td>
<td>&lt;0.0001</td>
<td>9 (10)</td>
<td>10 (25)*</td>
<td>17 (30)*</td>
<td>0.004</td>
</tr>
<tr>
<td>CHD, n (%)</td>
<td>68 (21)</td>
<td>98 (34)*</td>
<td>7 (8)*</td>
<td>&lt;0.0001</td>
<td>6 (6)</td>
<td>14 (35)*</td>
<td>9 (16)</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Numeric data are mean±SD, or median (25th–75th percentile) for skewed data. Categorical data are n (%). CHD indicates coronary heart disease; DBP, diastolic blood pressure; HOMA-IR, homeostasis model assessment of insulin resistance; and SBP, systolic blood pressure. *P<0.01, †P<0.05, compared with Europeans by post hoc test after ANOVA.
Ethnic Differences in LV Structure

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(Figure S2; \(P<0.0001\)), and that concentric remodeling was the most common form of remodeling, being more prevalent in South Asians (56.0%) and in African Caribbeans (55.6%) compared with Europeans (49.0%; \(P=0.001\)). However, concentric hypertrophy was substantially overestimated by conventional echocardiography and appeared more prevalent in African Caribbeans (\(P<0.0001\)). Eccentric hypertrophy was rare in all ethnic groups, and its frequency did not differ by ethnicity.

Potential Explanations of Ethnic Differences in LV Structure

We examined whether differences in LV structure between ethnic groups could be explained by differences in cardiovascular and metabolic risk factors. After accounting for potential explanatory variables (age, sex, systolic blood pressure, blood pressure-lowering medication, heart rate, HbA1c, fasting insulin, weight, total arterial compliance, and CHD: Model 2), 3D LVM (indexed to either body surface area or height\(^{2.7}\)) and LVRI in South Asians remained significantly lower than in Europeans (Table 4). Indexed 3D LV mass remained similar in African Caribbeans and Europeans, despite multivariate adjustment, but differences in LVRI between African Caribbeans and Europeans were attenuated after adjustment for cardiometabolic risk factors and were no longer statistically significant (Table 4). Findings persisted when HbA1c was replaced by fasting glucose, and when both fasting insulin and HbA1c, or glucose were replaced by HOMA-IR.

Discussion

In this population-based study, we found no difference in LV mass indexed to height\(^{2.7}\) or body surface area between African Caribbeans and Europeans using 3D echocardiography. In contrast, South Asian people had significantly smaller indexed LV mass, even after adjustment for cardiometabolic risk factors. Concentric remodeling was the most prevalent LV geometry in all ethnic groups. African Caribbeans had the highest prevalence of concentric remodeling, but this excess was abolished when their greater hyperglycemia and lower total arterial compliance were accounted for. Concentric remodeling related to insulin resistance, diabetes mellitus, and increased arterial stiffness, and could therefore contribute to the increased risk of HF observed in this ethnic group.\(^{9,20,21}\) These findings suggest that successful treatment to control modifiable risk factors in African Caribbeans could lessen remodeling and therefore progression to HF.

People of Black African descent in the United Kingdom have elevated rates of diabetes mellitus and stroke, but significantly less CHD, with mortality attributable to CHD in men being half that of the general population.\(^{22}\) Lower rates of CHD were also observed in African Americans in the United States in the early part of the last century,\(^{23}\) although this has been eroded.\(^{24}\) The similarity in 3D measured LV mass between

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### Table 2. Three-Dimensional Echocardiographic Measures of Left-Ventricular Structure and Systolic Function

<table>
<thead>
<tr>
<th>Variables</th>
<th>European (n=427)</th>
<th>South Asian (n=325)</th>
<th>African Caribbean (n=143)</th>
<th>(P) Value (ANOVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV mass, g</td>
<td>125.4±1.2</td>
<td>109.5±1.4*</td>
<td>123.5±2.2</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>LV mass/height(^{2.7}), g/m(^{2.7})</td>
<td>29.8±0.3</td>
<td>28.1±0.4*</td>
<td>29.0±0.5</td>
<td>0.0003</td>
</tr>
<tr>
<td>LV mass/BSA, g/m(^{2})</td>
<td>66.1±0.6</td>
<td>61.9±0.7*</td>
<td>65.2±1.1</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>LV EDV, mL</td>
<td>84.6±0.9</td>
<td>77.3±1.02*</td>
<td>79.0±1.6</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>LV EDVI, mL/m(^{2.7})</td>
<td>20.1±0.2</td>
<td>19.8±0.3</td>
<td>19.2±0.4</td>
<td>0.08</td>
</tr>
<tr>
<td>LVRI</td>
<td>1.52±0.02</td>
<td>1.47±0.02†</td>
<td>1.61±0.03†</td>
<td>0.0009</td>
</tr>
<tr>
<td>CO, L</td>
<td>3.49±0.04</td>
<td>3.10±0.05*</td>
<td>3.04±0.07*</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>SV, mL</td>
<td>51.2±0.5</td>
<td>47.0±0.6*</td>
<td>47.6±0.9</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>TPR, mm Hg/L</td>
<td>29.7±0.5</td>
<td>33.7±0.5*</td>
<td>35.3±0.8</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>TAC, mL/mm Hg</td>
<td>0.87±0.01</td>
<td>0.74±0.01*</td>
<td>0.78±0.02*</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Data are mean±SE by ethnicity (adjusted for age and sex). BSA indicates body surface area; CO, cardiac output; EDV, end diastolic volume; EDVI, indexing end diastolic volume; LV, left ventricular; LVRI, LV remodeling index; SV, stroke volume; TAC, total arterial compliance; and TPR, total peripheral resistance.

\(\ast P<0.01\), \(\dagger P<0.05\), compared with Europeans by post hoc test after ANOVA.

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### Table 3. Conventional (Two-Dimensional) Echocardiographic Measures of Left-Ventricular Structure

<table>
<thead>
<tr>
<th>Variables</th>
<th>European (n=427)</th>
<th>South Asian (n=325)</th>
<th>African Caribbean (n=143)</th>
<th>(P) Value (ANOVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LVID, cm</td>
<td>4.52±0.02</td>
<td>4.39±0.02*</td>
<td>4.46±0.03</td>
<td>0.0001</td>
</tr>
<tr>
<td>IVS, cm</td>
<td>1.15±0.1</td>
<td>1.10±0.1*</td>
<td>1.25±0.02*</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>PWT, cm</td>
<td>1.02±0.01</td>
<td>1.00±0.01*</td>
<td>1.09±0.01*</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>LV mass, g</td>
<td>176.3±2.1</td>
<td>159.8±2.4*</td>
<td>190.8±3.7*</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>LV mass/height(^{2.7}), g/m(^{2.7})</td>
<td>41.9±0.5</td>
<td>40.9±0.6</td>
<td>46.4±0.9</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>LV mass/BSA, g/m(^{2})</td>
<td>92.9±1.04</td>
<td>90.2±1.2</td>
<td>101.0±1.8*</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>RWT</td>
<td>0.46±0.004</td>
<td>0.46±0.004</td>
<td>0.49±0.007*</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Data are mean±SE by ethnicity (adjusted for age and sex). BSA indicates body surface area; IVS, interventricular septum at end diastole; LV, left ventricular; LVID, left-ventricular internal dimension at end diastole; PWT, posterior wall thickness at end diastole; and RWT, relative wall thickness.

\(\ast P<0.01\), compared with Europeans by post hoc test after ANOVA.
African Caribbeans and Europeans may be a consequence of the balance of protective and damaging risk factors. Previous studies using conventional echocardiography have reported that African Caribbeans in the United Kingdom have increased LV mass and increased LVH compared with Europeans.\textsuperscript{25–27} In the United States, comparisons of African Americans and whites are less consistent. Both the CARDIA (Coronary Artery Risk Development in Young Adults)\textsuperscript{31} and Dallas heart study\textsuperscript{28} reported that African Americans had an increased LV mass and a higher prevalence of LVH. Increased LV mass and prevalence of LVH in African Americans compared with whites have also been reported in some studies of people with hypertension in the United States.\textsuperscript{29,30} However, no significant differences in LV mass between African Americans and whites was reported in stroke-free control participants in the NOMAS (North Manhattan Stroke Study),\textsuperscript{31} in young adults who participated in the Bogalusa study,\textsuperscript{32} or in another smaller study of healthy young black and white adults.\textsuperscript{33} A study of US participants in the HOT (Hypertension Optimal Treatment) study also failed to observe differences in LV mass between African Americans and whites.\textsuperscript{34} Whether these inconsistencies relate to the selection, age, or size of the samples investigated is unclear. Nevertheless, our findings suggest that previously reported differences based on likely inappropriate geometric assumptions may have misrepresented interethnic differences in LV structure. Interestingly, and consistent with our findings, a recent cardiac MRI substudy of MESA also did not find a significant difference in LVMI between non-Hispanic black and white populations, although this study was limited to individuals without cardiovascular risk factors.\textsuperscript{35} Different patterns of remodeling in white Europeans and African Caribbeans are likely to result in an overestimation of LV mass and over diagnosis of LVH in African Caribbeans when conventional echocardiography is used, with implications for risk assessment in this ethnic group.

South Asians in the United Kingdom also have an increased prevalence of systolic HF\textsuperscript{36} that develops at an earlier age,\textsuperscript{9} possibly as a consequence of increased atheromatous disease and CHD. However, despite this increased prevalence of HF, South Asians with HF have a better prognosis than Europeans,\textsuperscript{37} whether this relates to the lower indexed LV mass observed in this study merits further investigation. Data comparing LV mass and LV remodeling patterns between South Asians and Europeans are limited. Both direct and indirect comparisons in people free of known CVD suggest that South Asian people have lower indexed LV mass.\textsuperscript{8,36} We extend these findings to the general population and further show that the lower LV mass in South Asians is not explained by differences in CVD risk factors or metabolic parameters. The explanation for the lower LV mass in South Asian people is unknown; it is possible that it simply reflects inappropriate allometric indexation for body size. However, if it does not, it would be expected to lead to an increase in active LV wall stress and myocardial oxygen demand.\textsuperscript{37} This might increase vulnerability to myocardial ischemia and contribute to the increased rates of myocardial infarction in South Asians,\textsuperscript{4} although this hypothesis requires further investigation.

The results of this study highlight the importance of acquiring geometrically accurate LV mass. Three-dimensional echocardiography provides a direct estimate of LV mass, unlike conventional echocardiography, which calculates LV mass using assumptions about ventricular geometry that may not be valid in people of different ethnicities. Indexed LV mass was higher by conventional echocardiography in all ethnic groups, especially in African Caribbeans, and there was marked disagreement in the prevalence of LVH when results of conventional and 3D echocardiography were compared. Similar observations showing overestimation of LV mass by conventional echocardiography have been made in other studies of individuals with and without cardiac disease using both MRI and 3D echocardiography.\textsuperscript{38,39} Our data could also imply that the allometric scaling used to correct for the impact of body size when reporting LV mass performs less well in non-European origin populations for which these indices were designed and tested. Thus, ethnic-specific normal reference ranges may need to be established to ensure appropriate assessment of LVH and risk estimation.\textsuperscript{40}

This study has a number of limitations. We studied survivors of an on-going longitudinal cohort: at the time of follow-up 26.3% of Europeans, 22.2% of South Asians, and 15.9% of African Caribbeans had died; those who survived and attended clinic were healthier at baseline than those who did not. Consequently, we cannot wholly exclude an influence of differential survival on our findings; however, these differences were similar by ethnic group and are unlikely to have substantially biased between ethnic group comparisons. Our observations in older people may not necessarily apply to younger individuals. Three-dimensional echocardiography has been shown to give estimates of LV mass that are very similar to MRI,\textsuperscript{38} but measurement of LV mass by 3D echocardiography cannot be performed in patients with poor acoustic windows. Although inability to image did lead to some losses of the study population, the characteristics of people in whom 3D data could not be collected did not differ by ethnicity and,
therefore, is unlikely to have biased comparisons between ethnic groups. Previous reports of a half SD difference in LV mass for South Asians, and a quarter SD difference for African Caribbeans, were easily detectable given the sample size of our study. Normal limits for 3D LV mass are less well studied, and this may introduce some uncertainty into the classification of LV remodeling, but this is unlikely to alter our conclusions substantively.

Conclusion

Despite greater risks of CHD, stroke, and diabetes mellitus, South Asians have lower indexed LV mass than Europeans, unexplained by body size or cardiometabolic risk factors. In contrast, indexed 3D LV mass is similar in African Caribbeans and Europeans. Increased concentric remodeling related to hypertension and diabetes mellitus may contribute to the increased risk of HF in African Caribbeans.

Perspectives

We highlight the importance of 3D echocardiography in providing accurate measures of LV structure, with important implications for cardiovascular risk assessment. Low LV mass in South Asians, which persists on multivariate adjustment, might indicate that current allometric approaches used to index LV mass are inappropriate for this population; alternatively, it may be of pathological importance. Assessment of LV structure should assess remodeling patterns as well as mass by 3D echocardiography.

Acknowledgments

We thank the SABRE (Southall And Brent REvisited) participants and the SABRE team.

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Disclosures

None.

References

16. Lang RM, Bierig M, Devereux RB, Flachskampf FA, Foster E, Pellikka PA, Picard MH, Roman MJ, Seward J, Shanewise JS, Solomon SD, Spencer KT, Sutton MS, Stewart WJ. Recommendations for chamber quantification: a report from the American Society of Echocardiography’s Guidelines and Standards Committee and the Chamber Quantification Writing Group, developed in conjunction with the European Association of Echocardiography, a branch of the European Society of Cardiology. J Am Soc Echocardiogr. 2005;18:1440–1463.
28. Drazner MH, Dries DL, Peshock RM, Cooper RS, Klassen C, Kazi F, Willet D, Victor RG. Left ventricular hypertrophy is more prevalent in

**Novelty and Significance**

**What Is New?**

- Left-ventricular 3-dimensional mass is lower in South Asians and equivalent in African Caribbeans compared with Europeans, even when cardiometabolic risk factors are accounted for.
- There is a marked disagreement in the prevalence of left-ventricular hypertrophy when results of conventional and 3-dimensional echocardiography are compared, particularly in African Caribbeans.

**What Is Relevant?**

- Low left-ventricular mass in South Asians might indicate that current allometric approaches used to index left-ventricular mass are inappropriate for this population; alternatively, it may be of pathological importance via its implications for myocardial wall stress and oxygen demand.

**Summary**

Geometric assumptions used to estimate left-ventricular structure using conventional echocardiography may be misleading when applied to non-European ethnic groups.
Left-Ventricular Structure in the Southall And Brent REvisited (SABRE) Study: Explaining Ethnic Differences

Chloe M. Park, Katherine March, Arjun K. Ghosh, Siana Jones, Emma Coady, Claire Tuson, Darrel Francis, Jamil Mayet, Therese Tillin, Nish Chaturvedi and Alun D. Hughes

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Title: LEFT VENTRICULAR STRUCTURE IN THE SABRE STUDY: EXPLAINING
ETHNIC DIFFERENCES

Chloe M Park, PhD, Katherine March, BSc, Arjun K Ghosh, MRCP, Siana Jones, MSc,
Emma Coady, RGN, Claire Tuson, RGN, Darrel Francis, MD, Jamil Mayet, MD, Therese
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Short title: Ethnic differences in left ventricular structure

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Extended methods:

3D echocardiography calculated variables
- Stroke volume (SV) = (EDV-ESV)
  where EDV and ESV are 3D end diastolic and systolic volume
- Cardiac output (CO) = SV x heart rate (HR)
- Total peripheral resistance (TPR) = MAP/CO
  where MAP is mean arterial pressure
- Total arterial compliance (TAC) = SV/PP
  where PP is pulse pressure
- Left ventricular remodelling index (LVRI) = LV mass/EDV

M-mode and 2D echocardiography calculated variables
- LV mass(2D) = 0.8 *(1.04 *((IVS(d)+ LVID(d)+ PWT(d))3- LVID(d))3) +0.6
- RWT =2 x PWT(d)/LVID(d)
  where IVS(d) is interventricular septal thickness, PWT(d) is posterior wall thickness and LVID(d) is left ventricle internal diameter (all measured at end diastole (d)).
Table S1: Differences in baseline (ie at recruitment 1988-90) characteristics between non-clinic and clinic attendees stratified by ethnicity

<table>
<thead>
<tr>
<th>Variable</th>
<th>European</th>
<th>South Asian</th>
<th>African Caribbean</th>
<th>Non-clinic v clinic attendees</th>
<th>Ethnicity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean difference</td>
<td>Mean difference</td>
<td>Mean difference</td>
<td>P value</td>
<td>P value</td>
</tr>
<tr>
<td>Male (%)</td>
<td>-6.6</td>
<td>-4.9</td>
<td>6.5</td>
<td>0.003</td>
<td>0.7</td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>2.2</td>
<td>1.3</td>
<td>1.5</td>
<td>&lt;0.0001</td>
<td>0.1</td>
</tr>
<tr>
<td>Weight (Kg)</td>
<td>-0.2</td>
<td>1.3</td>
<td>0.1</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>4.0</td>
<td>2.0</td>
<td>4.0</td>
<td>&lt;0.0001</td>
<td>0.5</td>
</tr>
<tr>
<td>Fasting glucose (mmol/l)</td>
<td>0.1</td>
<td>0.3</td>
<td>0.2</td>
<td>0.0005</td>
<td>0.3</td>
</tr>
<tr>
<td>Fasting HbA1c (%)</td>
<td>0.1</td>
<td>0.1</td>
<td>-0.3</td>
<td>0.02</td>
<td>0.08</td>
</tr>
<tr>
<td>Diabetes (%)</td>
<td>2.95</td>
<td>4.40</td>
<td>5.0</td>
<td>&lt;0.0001</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Data are mean difference of the results from the non-clinic attendees group minus the clinic attendees group. The p value for ethnicity is for the interaction term.
Table S2: Differences in characteristics of individuals in which only 2D was possible compared to those who had both 2D and 3D echo, by ethnicity

<table>
<thead>
<tr>
<th>Variable</th>
<th>European Mean difference</th>
<th>South Asian Mean difference</th>
<th>African Caribbean Mean difference</th>
<th>2D only v 2D and 3D P value</th>
<th>Ethnicity P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male (%)</td>
<td>-1</td>
<td>-7.3</td>
<td>-28.2</td>
<td>0.001</td>
<td>0.06</td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>0.2</td>
<td>-0.2</td>
<td>-0.1</td>
<td>0.9</td>
<td>0.8</td>
</tr>
<tr>
<td>Weight (Kg)</td>
<td>10.6</td>
<td>6.5</td>
<td>8.0</td>
<td>&lt;0.0001</td>
<td>0.07</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>-1.9</td>
<td>0.7</td>
<td>-1.0</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Fasting glucose (mmol/l)</td>
<td>0.35</td>
<td>0.56</td>
<td>0.44</td>
<td>&lt;0.0001</td>
<td>0.6</td>
</tr>
<tr>
<td>HbA1c (%)</td>
<td>0.36</td>
<td>0.42</td>
<td>0.34</td>
<td>&lt;0.0001</td>
<td>0.9</td>
</tr>
<tr>
<td>Diabetes (%)</td>
<td>13.4</td>
<td>13.3</td>
<td>16.1</td>
<td>&lt;0.0001</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Data are mean difference of the 2D only group minus the 2D and 3D group. The p value for ethnicity is for the interaction term.
Figure S1: Mean differences between conventional and 3D measured a) LVMI$^{2.7}$ and b) LVMI stratified by ethnicity.
Figure S2: Frequency distribution of the four left ventricle geometric patterns indexed to BSA by ethnicity: a) 3D echocardiography b) conventional echocardiography.