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Low Cardiovascular Risk Is Associated with Favorable Left Ventricular Mass, Left Ventricular Relative Wall Thickness, and Left Atrial Size: The CARDIA Study

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Abstract

Background—Echocardiographic measures of left ventricular (LV) mass and relative wall thickness and left atrial (LA) size predict future cardiovascular morbidity and mortality. The aim of this study was to compare young adults with low cardiovascular risk (body mass index, 18.5–24.9 kg/m²; blood pressure < 120/80 mmHg; no tobacco use, no diabetes, and physical fitness) with those without these characteristics with regard to LV mass and relative wall thickness and LA size, to determine the protective effect of a healthy lifestyle on the development of these characteristics.

Methods—Cross-sectional assessment of 4059 black and white men and women aged 23 to 35 years in the Coronary Artery Risk Development in Young Adults (CARDIA) study at the year 5-examination, when risk factors were measured, and echocardiography to assess LV mass and relative wall thickness were performed. Physical fitness was measured at baseline using a symptom-limited maximal treadmill test. All other covariates were measured concurrently with echocardiography.

Results—Gender, body mass index, and systolic blood pressure were associated with LV mass and relative wall thickness and LA size in multivariate models. Additional correlates of LV mass/height^{2.7} ratio were tobacco use, resting heart rate (inverse), self-reported physical activity, gender (male higher), and age. Age was associated with LV relative wall thickness but not other measures of LV size. Additional correlates of LA diameter/height ratio were tobacco use, resting heart rate (inverse), serum glucose, and self-reported physical activity. Seven hundred ninety of 4059 subjects (19%) were classified as having low risk; black race was less likely in the low-risk group. Those with low risk had lower LV mass/height^{2.7} ratios (32.0 vs 34.6 g/m^{2.7}, $P < .0001$), better LV

relative wall thickness (0.33 vs 0.35, $P < .0001$), and lower LA diameter/height ratios (2.02 vs 2.08 cm/m, $P < .01$).

Conclusions—A low cardiovascular risk profile in young adulthood is associated with more favorable LV mass, LV relative wall thickness, and LA size. This may be one mechanism of lifestyle protection against cardiovascular morbidity and mortality.

Keywords

Left ventricular mass; Hypertension; Obesity; Cardiovascular risk factors

Echocardiographic measures of left ventricular (LV) mass and relative wall thickness (the ratio of LV wall thickness to LV diameter) and left atrial (LA) size are important independent predictors of cardiovascular morbidity and mortality, particularly congestive heart failure, coronary artery disease, stroke, and atrial fibrillation.^{1–7} Abnormalities of LV mass and relative wall thickness and LA size in individuals with other cardiovascular risk factors, most importantly obesity and hypertension, can be detected in children and young adults, long before cardiovascular morbidity occurs.^{8–11} Increases in body weight and blood pressure are important predictors of increasing LV mass and suboptimal LV relative wall thickness.^{12–15} Conversely, some factors associated with cardiovascular health, low resting heart rate and high levels of physical fitness, are also associated with higher LV mass.^{16,17}

Studies of individuals with healthy lifestyles and low cardiovascular risk have shown very low rates of cardiovascular disease.¹⁸ Part of this health benefit may be from the prevention of chronic strain on the heart caused by excess body weight, elevated blood pressure, and tobacco use. Prior work in this field has not investigated the association of a low cardiovascular risk factor profile on LV mass and relative wall thickness and LA size. No prior studies have investigated the association of physical fitness with LV mass and relative wall thickness and LA size in a population-based cohort, as opposed to studies of trained athletes.

The Coronary Artery Risk Development in Young Adults (CARDIA) study is a prospective study of cardiovascular risk development in young white and black men and women. At baseline, individuals were aged 18 to 30 years, and echocardiography was performed in year 5.⁹ Prior analyses of LV structure and function in the CARDIA cohort have shown that in young adults, the most important determinants of LV mass and relative wall thickness are body size and blood pressure; additional determinants are tobacco use, physical activity, male gender, and possibly race.^{9,11,12} The importance of physical fitness on these measures and the determinants of LA diameter have not previously been studied in CARDIA. The purpose of this study was to determine the health benefit of normal body mass index (BMI), normal blood pressure, absence of tobacco use, and relative physical fitness on LV mass and relative wall thickness and LA diameter in young adults.

METHODS

Details regarding the overall design, recruitment, and overall methods of the CARDIA study have been previously published.¹⁹ The CARDIA study is a longitudinal study of acquisition

of cardiovascular risk factors in young adults recruited at age 18 to 30 years. The cohort was selected from the general population to include black and white men and women, about half of whom had more than a high school education and half had less. The year 25 examination will occur in 2010 and 2011. In year 5, of the CARDIA study, echocardiography was performed at 4 sites: Chicago, Illinois; Minneapolis, Minnesota; Birmingham, Alabama; and Oakland, California. The protocol has been previously described.⁹ Briefly, 2-dimensionally guided M-mode echocardiography was performed, and measurements of the left ventricle and left atrium were made according to American Society of Echocardiography guidelines using a parasternal window and long-axis and short-axis views.²⁰ Tracings were not analyzed if the eccentricity index on comparison of views was > 1.3 . First the desired interface was identified using the thinnest continuous echo lines, and then the leading edge of the anterior and posterior interfaces was identified for diameter measurement. LV mass was derived from the Devereux formula and indexed for body size by dividing by height^{2,7,11} LV relative wall thickness or geometry ratio was calculated as the ratio of the sum of ventricular septum and posterior wall thicknesses divided by LV internal diameter in diastole.¹¹ LA diameter was indexed to height.⁷ Studies were interpreted at a central reading center within 1 to 3 weeks of their performance. Echocardiograms were classified according to quality measures as fair, good, or excellent.

All measurements were collected using standardized protocols across all field centers.¹⁹ In brief, height and weight were measured in light clothing, and BMI was calculated as weight in kilograms divided by the square of height in meters. Cigarette smoking was determined by self-report. Physical activity was determined by questionnaire.²¹ After 5 minutes of rest, blood pressure was measured 3 times by random-zero sphygmomanometer, and the last 2 values were averaged; resting heart rate was also measured. Diabetes mellitus was defined by 1997 American Diabetes Association fasting glucose criteria at year 0 (glucose > 126 mg/dL) and by self-report of medication use at year 5. At the baseline examination, a graded symptom-limited treadmill exercise test was performed using the modified Balke protocol. This test uses a series of 2-minute stages, with treadmill speed (baseline, 3.0 mi/h; peak, 5.6 mi/h) and grade (baseline, 2%; peak, 25%) increased at each stage. Total treadmill time was used as the measure of fitness; energy expenditure for the lowest stage is 4.1 metabolic equivalents, increasing to 19.6 metabolic equivalents at peak. The correlation of fitness measured at year 0 with fitness measured at year 7 was 0.77, suggesting reasonable stability of the measure at examinations bracketing the year 5 examination.^{22,23} Blood lipid levels were not used in risk determination, because they are unrelated to measures of cardiac size and function.⁹

Low cardiovascular risk was defined as the simultaneous presence of blood pressure $< 120/80$ mm Hg, BMI of 18.5 to 24.9 kg/m², not diabetic, no current cigarette smoking, and treadmill time > 60 th percentile for gender.

Data Analysis

From the 4111 participants with available echocardiograms at the year 5 examinations, we excluded 45 participants who did not have fitness data at baseline and 7 more who were

missing height measurements at baseline. A total of 4059 participants were included in this cross-sectional analysis.

Descriptive statistics were calculated for all covariates of interest. Next, we standardized the continuous covariates (predictor variables of interest) to a mean of 0 and a standard deviation of 1. We then conducted a linear regression analysis to calculate β coefficients and standard errors of the association of these standardized covariates of interest with LV mass and LA diameter. Next, we ran a series of multivariate linear regression models that included race, gender, age, blood pressure, BMI, heart rate, physical activity score, treadmill time, cigarette smoking status, and fasting glucose as predictors of LV mass, LV mass indexed for height^{2.7}, LV relative wall thickness, and LA diameter indexed for height. We tested for interaction by race in the association of health status with echocardiographic parameters separately by gender using a multiplicative interaction term between race and health status in linear regression models that also included lower order terms. After identifying interaction (multiplicative interaction term $P < .05$) between health status and race among women, we conducted further analyses stratified by both sex and race. We calculated means and 95% confidence intervals of the association between low risk factor status and each of the echocardiographic variables separately by race-sex groups. Finally, the cohort was stratified into 4 groups according to the presence of LV hypertrophy (LV mass $> 46.7 \text{ g/m}^{2.7}$ in women and $> 49.2 \text{ g/m}^{2.7}$ in men) and the presence of eccentric or concentric LV geometry (a ratio > 0.43 implies eccentric geometry).^{24,25} Comparisons between low-risk and non-low-risk groups were made using t tests. Statistical significance was determined at $P < .05$. All analyses were conducted using SAS version 9.1 (SAS Institute Inc, Cary, NC).

RESULTS

The distribution of echocardiographic parameters in the total sample and stratified by sex is reported in Table 1. All of the echocardiographic parameters were smaller in women compared with men.

Blacks were less likely to have low optimal health status. For the entire group with nonoptimal health status, blood pressure was 5.3/3.9 mm Hg higher, BMI was 3.4 kg/m² higher, treadmill duration was 3 minutes less, and self-reported physical activity was 75 exercise units less.

Univariate correlates of LV mass and LA diameter are shown in Table 2. With the exception of former smoking, all variables were significantly associated with LV mass. All variables were significantly associated with LA diameter, except for treadmill duration. LV mass was larger with increasing BMI, activity level, treadmill duration, and systolic and diastolic blood pressure and lower with increasing heart rate. Black participants, men, and current smokers had larger LV mass than white participants, women, and nonsmokers, respectively. The direction of association with LA diameter was similar.

In both women and men, BMI, current smoking and systolic blood pressure were positively associated with LV mass/height^{2.7}, and heart rate was inversely associated with LV mass/height^{2.7} (Table 3) independent of other cardiovascular disease risk factors. Among men, age

was also positively associated with LV mass/height^{2.7}, whereas among women, black race was positively associated with LV mass/ height^{2.7}. In a multivariate model describing the association with LV relative wall thickness, black race, BMI, and systolic blood pressure were positively associated with LV relative wall thickness in women and men. Multivariate correlates of LA diameter/height among women were BMI, current and former smoking (compared with never smoking), heart rate (inverse), and systolic blood pressure. By contrast, multivariate correlates of LA diameter/height among men were age, BMI, current smoking, heart rate (inverse), systolic blood pressure, and physical activity.

Table 4 shows differences in geometric means for all echocardiographic parameters between those with optimal compared with non-optimal health status across race and sex groups. Among both white and black women, LV mass, LV mass/height^{2.7}, and LA diameter/ height were significantly smaller among women who had optimal health status compared with those who did not. LV relative wall thickness was significantly smaller in black women with optimal health compared with nonoptimal health, but the differences were not significant among white women. The magnitudes of the differences in LV mass, LV mass/height^{2.7}, and LV relative wall thickness by health status were significantly greater in black women compared with white women (P for interaction between race and health status < .05 for all 3 variables).

Differences in LV mass and LV mass/height^{2.7} by health status were present in white and black men but were less pronounced for white men (trend) than black men (statistically significant). LV relative wall thickness and LA diameter/height were significantly lower in both white and black men with optimal compared with nonoptimal health status. There was no evidence of statistical interaction in the association of health status with echocardiographic parameters in white versus black men.

Table 5 compares the prevalence of normal heart size and geometry, eccentric LV geometry, concentric LV hypertrophy, and eccentric LV hypertrophy in those with optimal versus nonoptimal health status and the remainder of the cohort. The difference in distribution between groups was highly significant (P < .0001), with the nonoptimal group having a distribution of prevalence skewed toward abnormality.

DISCUSSION

Low cardiovascular disease risk profiles (ie, optimal health status) were associated with lower LV mass, better LV relative wall thickness, and lower LA diameter in the present study. Although longitudinal population-based data on echocardiographic measures are limited, this study suggests that maintaining optimal BMI, blood pressure, non-smoking status, and physical fitness for the first 3 to 4 decades of life minimizes adverse differences in echocardiographic measures of risk. With aging, echocardiographic parameters become more adverse. Comparisons of data from middle-aged to older cohorts with CARDIA suggest substantial cumulative effect of risk on heart size; for example, mean indexed LV mass in middle-aged to older African Americans in Mississippi is substantially higher than in the CARDIA cohort.²⁶

In CARDIA, black race was associated with higher and larger LV mass and geometry between those with optimal health status and those without. For black women, the observed race-gender interaction may be explained by the higher prevalence of obesity.^{9,12} BMI was substantially higher in black women, so the difference in BMI between the optimal and nonoptimal risk groups was greatest in this race-gender group. Over a 5-year interval in this cohort, LV mass increased only in black women, and this was related to excess weight gain. Blacks with hypertension have more abnormal LV geometry than whites.^{27,28}

Correlates of LA size have not been previously examined in CARDIA. Compared with other reported cohorts, the CARDIA data set is much larger and does not include individuals with significant cardiac disease. As in other studies, the most important correlates are BMI and blood pressure.^{7,29,30} Additional significant effects were seen for female gender, resting heart rate, and tobacco use, with additional small effects associated with blood glucose and self-reported physical activity. Increased LA size is known to be a component of the athletic heart. Gender has not been shown in prior studies to be associated with LA size after adjustment for blood pressure and body size.⁷ Interestingly, as in this study, elevated blood glucose has been associated with LA size.²⁹ Tobacco use has not previously been reported to be associated with LA size, though a recent study has associated tobacco use with LA fibrosis.³¹ A limitation of this analysis was the reliance on LA diameter measurements from two-dimensionally guided M-mode echocardiography rather than the LA area measurements more commonly done in contemporary studies.

The current literature on the relationship of heart size and function to athletic performance generally compares well-trained athletes with sedentary individuals. Participating in rigorous athletic training is known to increase LV mass by about 10%.¹⁷ However, studies of echocardiographic parameters of heart size and geometry, including the range of fitness encountered in a population-based cohort as opposed to trained athletes, have not been reported. In this study, physical fitness and self-reported physical activity had minimal impacts on LV mass, LV relative wall thickness, and LA size; lower heart rate was associated with increased LV mass. Very few CARDIA participants train physically as athletes, which may explain the lack of association seen in this study. The association with heart rate most likely represents a balance between stroke volume and heart rate to maintain normal resting cardiac output. Most important, being more fit (and having higher mass or atrial diameter) did not confound assessment of the health benefit of optimal blood pressure or BMI with regard to echocardiographic measures.

LV hypertrophy, abnormal LV relative wall thickness, and LA dilation confer independent risk for many cardiovascular outcomes, including congestive heart failure, coronary artery disease, and atrial fibrillation.¹⁻⁷ This study suggests that the development of these traits begins in youth and is secondary to chronic exposure to overweight, higher blood pressure, and tobacco use.^{12,13} Prior studies of these measures have focused on the association with cardiovascular risk factors and future cardiovascular morbidity and mortality. This analysis highlights the importance of maintenance of cardiovascular health on prevention of cardiac end-organ injury.

There is limited information on the reversibility of these echocardiographic measures or whether there are age-related thresholds at which the heart's ability to adapt is compromised. Longitudinal analyses of children and young adults suggest that change in body size is an important determinant of change in LV mass.^{12,13} Thus, at younger ages, weight management is effective. In CARDIA, LV mass remained stable over a 5-year follow-up interval in a subsample of the cohort reported in this study, with the exception of black women, in whom the increase in LV mass was explained by significant interval weight gain. Recent studies of pharmacologic treatment of hypertension have shown regression of LV mass with effective treatment, and this regression is associated with improvements in outcome.⁴

The Pathobiological Determinants of Atherosclerosis in Youth (PDAY) risk score, developed from the association of cardiovascular risk factors measured postmortem and atherosclerosis measured directly in the PDAY study, has been applied to the CARDIA study. Low cardiovascular risk and maintenance of low cardiovascular risk are associated with substantially lower risk for future development of coronary calcium; in fact, the likelihood of coronary calcium in the year 15 CARDIA examination in someone high risk at baseline and with increasing risk over time is 9 times that of someone with low risk at baseline and sustained low risk over the 15 years of the study.³² The echocardiographic findings in this study are consistent with the subclinical atherosclerosis observation. Sustaining the absence of cardiac target-organ injury through not smoking, maintaining optimal body weight, maintaining optimal blood pressure, and being physically fit may be the most important weapon in the fight against heart disease.³³

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Abbreviations

BMI	Body mass index
CARDIA	Coronary Artery Risk Development in Young Adults
LA	Left atrial
LV	Left ventricular

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Table 1

Distribution of LV mass markers and LA diameter

Variable	Total sample (n = 4059)	Women (n = 2228)	Men (n = 1831)
LV mass (g)	149.6 ± 44.7	130.5 ± 36.7	172.8 ± 42.5
LV relative wall thickness	0.348 ± 0.058	0.343 ± 0.058	0.354 ± 0.058
LA diameter (cm)	3.53 ± 0.47	3.42 ± 0.45	3.66 ± 0.46
LV mass/ height ^{2.7} (g/m ^{2.7})	35.2 ± 9.3	34.1 ± 9.5	36.6 ± 8.8
LA diameter/height (cm/m)	2.07 ± 0.27	2.08 ± 0.28	2.06 ± 0.26

Data are expressed as mean ± SD.

Table 2

Difference in echocardiographic parameters by demographic characteristics and cardiovascular disease risk factors

Variable	LV mass [*]		LA diameter [†]	
	β	SE	β	SE
Age (per 3.6 y)	2.18	0.70	0.031	0.007
Race (black vs white)	7.28	1.40	0.039	0.015
Gender (male vs female)	42.30	1.24	0.239	0.014
Smoking status				
Current vs never	6.29	1.61	0.043	0.022
Former vs never	-1.55	2.08	0.048	0.017
Glucose (per 14.1 mg/dL)	5.02	0.70	0.049	0.007
BMI (per 5.8 kg/m ²)	15.87	0.66	0.201	0.007
Physical activity (per 293 exercise units)	7.15	0.70	0.048	0.007
Baseline treadmill duration (per 3.09 min)	6.56	0.69	0.010	0.007
Heart rate (per 4.9 beats/min)	-7.02	0.69	-0.065	0.007
SBP (per 11.4 mm Hg)	15.72	0.66	0.107	0.007
DBP (per 9.9 mm Hg)	10.71	0.68	0.063	0.007

DBP, Diastolic blood pressure; SBP, systolic blood pressure.

Beta coefficients were calculated per standard deviation difference or comparing one level with the referent. The referent group is listed second.

^{*} All *P* values < .01 except for former smoking (*P* = .46).

[†] All *P* values < .01 except for treadmill duration (*P* = .16).

Table 3
Multivariate-adjusted* demographic and cardiovascular correlates of echocardiographic parameters

Risk characteristic	Women			Men		
	β	SE	P	β	SE	P
LV mass						
Age (per years)	1.68	0.69	.02	1.31	0.93	.16
Race (black vs white)	0.44	1.58	.78	1.42	1.92	.46
BMI (per 5.8 kg/m ²)	13.23	0.72	<.01	21.04	1.25	<.01
Treadmill duration (per 3.09 min)	0.97	1.06	.36	1.66	1.20	.17
Smoking status						
Current vs never	6.38	1.64	<.01	7.86	2.11	<.01
Former vs never	3.87	2.01	.05	-2.53	2.85	.37
Heart rate (per 4.9 beats/min)	-2.28	0.71	<.01	-6.47	1.00	<.01
SBP (per 11.4 mm Hg)	6.56	0.79	<.01	6.00	0.97	<.01
Glucose (per 14.1 mg/dL)	1.19	0.71	.09	1.04	0.89	.24
Physical activity (per 293 exercise units)	1.68	0.85	.05	2.63	0.85	<.01
LV mass/height ^{2.7} (g/m ^{2.7})						
Age (per years)	0.35	0.18	.05	0.22	0.19	.26
Race (black vs white)	0.54	0.41	.18	0.94	0.40	.02
BMI (per 5.8 kg/m ²)	3.50	0.18	<.01	4.40	0.26	<.01
Treadmill duration (per 3.09 min)	-0.16	0.27	.55	0.20	0.25	.43
Smoking status						

Risk characteristic	Women			Men		
	β	SE	P	β	SE	P
Current vs never	1.52	0.42	<.01	1.98	0.44	<.01
Former vs never	0.77	0.52	.13	-0.41	0.59	.49
Heart rate (per 4.9 beats/min)	-0.56	0.18	<.01	-1.38	0.21	<.01
SBP (per 11.4 mm Hg)	1.41	0.20	<.01	0.98	0.20	<.01
Glucose (per 14.1 mg/dL)	0.21	0.18	.25	0.08	0.19	.66
Physical activity (per 293 exercise units)	0.19	0.22	.38	0.28	0.18	.11
LV relative wall thickness						
Age (per years)	0.002	0.001	.06	0.002	0.001	.08
Race (black vs white)	0.013	0.003	<.01	0.018	0.003	<.01
BMI (per 5.8 kg/m ²)	0.003	0.001	.04	0.006	0.002	<.01
Treadmill duration (per 3.09 min)	-0.001	0.002	.51	-0.002	0.002	.22
Smoking status						
Current vs never	0.004	0.003	.16	0.006	0.003	.08
Former vs never	0.0001	0.004	.98	-0.002	0.004	.64
Heart rate (per 4.9 beats/min)	0.001	0.001	.41	0.0004	0.002	.76
SBP (per 11.4 mm Hg)	0.006	0.001	<.01	0.003	0.001	.02
Glucose (per 14.1 mg/dL)	0.002	0.001	.16	0.001	0.001	.45
Physical activity (per 293 exercise units)	0.001	0.002	.38	0.0004	0.001	.77
Left atrial diameter/height (cm/m)						
Age (per years)	-0.002	0.005	.69	0.017	0.006	<.01

Risk characteristic	Women			Men		
	β	SE	P	β	SE	P
Race (black vs white)	0.002	0.012	.87	-0.021	0.012	.07
BMI (per 5.8 kg/m ²)	0.121	0.005	<.01	0.133	0.008	<.01
Treadmill duration (per 3.09 min)	0.006	0.008	.44	-0.003	0.007	.70
Smoking status						
Current vs never	0.049	0.012	<.01	0.044	0.013	<.01
Former vs never	0.040	0.015	.01	0.013	0.018	.47
Heart rate (per 4.9 beats/min)	-0.028	0.005	.04	-0.041	0.006	<.01
SBP (per 11.4 mm Hg)	0.012	0.006	.04	0.014	0.006	.02
Glucose (per 14.1 mg/dL)	0.008	0.005	.12	0.010	0.006	.08
Physical activity (per 293 exercise units)	0.006	0.006	.34	0.011	0.005	.03

SBP, Systolic blood pressure.

* Derived from multivariate model. Continuous variables per standard deviation difference from the median. Categorical variables compared with the referent level, which is listed last.

Table 4Means and 95% confidence intervals of echocardiographic parameters, * stratified by race and sex[†]

Variable	Health Status		<i>P</i> [‡]
	Optimal	Not Optimal	
White women	n = 335	n = 767	
LV mass	121.2 (117.9–124.5)	126.9 (124.4–129.3)	<.01
LV mass/height ^{2.7}	31.4 (30.5–32.2)	32.7 (32.1–33.3)	.02
LV relative wall thickness	0.332 (0.326–0.338)	0.334 (0.330–0.338)	.58
LA diameter/height	2.01 (1.98–2.03)	2.06 (2.04–2.07)	<.01
Black women	n = 117	n = 1009	
LV mass	119.4 (114.1–124.7)	137.6 (135.1–140.1)	<.01
LV mass/height ^{2.7}	31.3 (30.0–32.6)	36.3 (35.7–37.0)	<.01
LV relative wall thickness	0.337 (0.325–0.348)	0.353 (0.350–0.357)	<.01
LA diameter/height	2.05 (2.01–2.10)	2.13 (2.11–2.15)	<.01
White men	n = 247	n = 734	
LV mass	167.4 (162.5–172.3)	170.2 (167.2–173.1)	.35
LV mass/height ^{2.7}	34.9 (33.9–35.9)	35.8 (35.2–36.4)	.16
LV relative wall thickness	0.339 (0.333–0.345)	0.347 (0.343–0.351)	.05
LA diameter/height	2.02 (1.99–2.05)	2.07 (2.05–2.09)	.01
Black men	n = 91	n = 759	
LV mass	167.4 (159.4–175.4)	177.7 (174.5–180.9)	.04
LV mass/height ^{2.7}	35.6 (33.9–37.3)	38.0 (37.3–38.7)	.02
LV relative wall thickness	0.353 (0.341–0.363)	0.366 (0.362–0.371)	.02
LA diameter/height	1.99 (1.94–2.04)	2.07 (2.05–2.09)	<.01

* Low-risk health status defined in individuals whose fitness is in the upper two sex-specific quintiles of treadmill test duration (women, >8.8 minutes; men, >12.2 minutes), never smoking, optimal weight (BMI > 18.5–24.9 kg/m²), optimal blood pressure (diastolic < 80 mm Hg, systolic < 120 mm Hg, and no use of blood pressure medications), and normal fasting glucose at baseline (glucose < 100 mg/dL) and no use of diabetes control medications at baseline, year 2 or year 5.

[†] Statistical significance based on a *t* test.

[‡] Interactions by race within sex groups as follows: LV mass women, *P* = .003; LV mass men, *P* = .18; LV mass/height^{2.7} women, *P* < .01; LV mass/height^{2.7} men, *P* = .19; LV geometry women, *P* = .03; LV geometry men, *P* = .46; LAD/height women, *P* = .47; LAD/height men, *P* = .35.

Table 5Prevalence of abnormal LV mass and/or geometry in health status ^{*} groups

Geometry	Optimal health status	Nonoptimal health status
Normal [†]	723 (91.5%)	2759 (84.4%)
Eccentric geometry [‡]	30 (3.8%)	211 (6.5%)
Concentric hypertrophy [§]	241 (4.1%)	32 (4.1%)
Eccentric hypertrophy ^{//}	58 (0.6%)	58 (1.8%)

^{*} Low-risk health status defined in individuals whose fitness is in the upper two sex-specific quintiles of treadmill test duration (women, >8.8 minutes; men, >12.2 minutes), never smoking, optimal weight (BMI > 18.5–24.9 kg/m²), optimal blood pressure (diastolic < 80 mm Hg, systolic < 120 mm Hg, and no use of blood pressure medications), and normal fasting glucose at baseline (glucose < 100 mg/dL) and no use of diabetes control medications at baseline, year 2 or year 5.

[†] Normal LV mass and relative wall thickness.

[‡] Normal LV mass and increased LV relative wall thickness.

[§] Increased LV mass and normal relative wall thickness.

^{//} Increased LV mass and increased LV relative wall thickness.