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Relation of Cardiovascular Risk Factors to Right Ventricular Structure and Function as Determined by Magnetic Resonance Imaging (Results from the Multi-Ethnic Study of Atherosclerosis)

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Abstract

The impact of cardiovascular risk factors on the left ventricle is well known but their impact on right ventricle has not been studied using advanced imaging techniques. The purpose of this study was to determine the relation between cardiovascular risk factors and right ventricular (RV) structure and function and its interaction with the left ventricle. Cardiac magnetic resonance images were analyzed in 4204 participants free of clinical cardiovascular disease in the Multi-Ethnic Study of Atherosclerosis. Multivariable linear regression models were used to study the cross sectional association between individual RV parameters and risk factors. All RV parameters except ejection fraction decreased with age ($p < 0.0001$). RV mass was positively associated with systolic blood pressure (+0.4g, $p < 0.0001$) and high density lipoprotein (HDL) cholesterol (+0.2g, $p < 0.0001$); inversely with diastolic blood pressure (−0.3g, $p < 0.0001$) and total cholesterol (−0.2g, $p < 0.01$). RV end diastolic volume was positively associated with systolic blood pressure (+1.6ml, $p < 0.01$) and HDL cholesterol (+1.8ml, $p < 0.0001$); and inversely with diastolic blood pressure (−2.2 ml, $p < 0.0001$), total cholesterol (−1.4ml, $p < 0.0001$), current smoking (−2.7ml, $p < 0.05$) and diabetes mellitus (−3.1ml, $p < 0.01$). RV ejection fraction was positively related with systolic blood pressure (+1.0%, $p < 0.0001$), HDL cholesterol (+0.4%, $p < 0.0001$) and inversely with diastolic blood pressure (−0.7%, $p < 0.0001$). In conclusion, the mass and volumes of the right ventricle decrease with age. Cardiovascular risk factors, especially blood pressure and HDL cholesterol are associated with subclinical changes in RV mass and volumes.

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INTRODUCTION

Magnetic resonance imaging (MRI) has emerged as an accurate tool for right ventricular (RV) evaluation and is considered a standard of reference for evaluation of both the right and left ventricle ¹. Previous studies of RV function using MRI in healthy volunteers have included smaller number of participants and have not assessed the relation between cardiovascular risk factors such as age, diabetes mellitus, systolic & diastolic blood pressure, cholesterol and smoking with the RV mass and volumes, particularly in relationship to the left ventricle ²⁻⁶. The Multi-Ethnic Study of Atherosclerosis (MESA) is a multicenter prospective cohort study of individuals without clinical cardiovascular disease, in which cardiac MRI was performed to assess cardiac structure and function. The purpose of this study was to determine the relation between cardiovascular risk factors and the RV structure and function and its interaction with the left ventricle.

METHODS

The Multi-Ethnic Study of Atherosclerosis (MESA) is a multicenter prospective cohort study designed to study subclinical cardiovascular disease in individuals without previous clinical cardiovascular disease ⁷. In 2000–2002, MESA recruited 6,814 men and women ages 45–84 years old from six U.S. communities. MESA participants are non-Hispanic White, African-American, Hispanic, and Asian. Exclusion criteria included clinical cardiovascular disease (physician diagnosis of heart attack, stroke, transient ischemic attack, heart failure, or angina), current atrial fibrillation, any cardiovascular procedure, pregnancy, active cancer treatment, weight >300 lbs, serious medical condition which precluded long term participation, nursing home residence, cognitive inability, inability to speak English, Spanish, Cantonese, or Mandarin, plan to leave the community within five years, and chest computed tomography within the past year. The protocols of MESA and all studies described herein were approved by the Institutional Review Boards of all collaborating institutions and the National Heart, Lung and Blood Institute (NHLBI).

Consenting and eligible (without metal implants, device or fragment) participants underwent a cardiac MRI scan using 1.5T GE and Siemens scanners at the 6 MESA field centers. Cardiac MRI was performed using a standard protocol ⁸. The imaging was performed with a 4-element phased-array surface coil placed anteriorly and posteriorly with electrocardiogram gating and brachial artery blood pressure monitoring. All images were acquired during short breath-holding (12–15 seconds) at resting lung volume. Imaging consisted of fast gradient echo cine images of the heart with time resolution <50 msec. Quantitative analysis of the right ventricle was performed on 4204 participants with interpretable MRI scans.

Cardiac MRI examinations were transmitted to the reading center at Johns Hopkins Hospital in Baltimore, MD using DICOM transfer protocol. Image analysis was done on Windows workstations using the QMASS software (Medis, the Netherlands; Research version). Images were magnified to 250%, contrast was set to 55, image brightness was set to 55, and window width and level were set using the auto function in QMASS to minimum and maximum pixel values. Image analysis was done by two independent analysts who received extensive training in the MESA protocol and RV morphology. The endocardial and epicardial borders for the RV were contoured manually on the short axis cine images at the end-systolic and end-diastolic phase. Papillary muscles and trabeculae were included in the RV volume and excluded from RV mass based on preliminary training datasets showing greater reproducibility for the analysis ⁹. The outflow tract was included in the RV volume. Contours were modified at basal slices of the heart by carefully identifying the tricuspid valve so as to exclude the right atrium and avoid overestimation of the volumes. RV end-systolic (ESV) and end-diastolic volumes (EDV) were calculated using Simpson's rule; by summation of areas on each slice multiplied by the

sum of slice thickness and image gap. RV mass was determined at the end-diastole phase as the difference between end-diastolic epicardial and endocardial volumes multiplied by the specific gravity of the heart (1.05g/ml) 8. RV stroke volume (SV) was calculated by subtracting RV end-systolic volume from the end-diastolic volume. RV ejection fraction (EF) was calculated by dividing RV SV with RV EDV and multiplying by 100.

Reader variability in the assessment of RV mass and volumes was measured by re-reads selected randomly. The readers were masked to the results obtained from previous analyses. Outliers were defined as measures with a difference greater than two standard deviations from the mean relative difference. The outliers were reviewed and arbitrated by an experienced MRI physician.

Standard questionnaires were used to ascertain smoking (classified as never, former, and current). Height was measured to the nearest 0.1 cm with the subject in stocking feet. Weight was measured to the nearest pound with the subject in light clothing using a balanced scale. Resting blood pressure was measured using the Dinamap Monitor PRO 100 (Critikon, Tampa, FL) automated oscillometric device. Serum glucose after 12-hour fast was measured by rate reflectance spectrophotometry using thin film adaptation of the glucose oxidase method on the Vitros analyzer (Johnson & Johnson Clinical Diagnostics, Inc., Rochester, NY). The diagnosis of diabetes mellitus was based on the use of insulin or oral hypoglycemic medication or fasting glucose ≥ 126 mg/dl. Impaired fasting glucose was considered present if fasting glucose was between 100–125 mg/dl. High density lipoprotein (HDL) and total cholesterol were assessed using standard methods ¹⁰.

Data are presented as mean $\pm$ standard deviation for continuous variables and as percentages for discrete variables. Intra- and inter-reader variability was determined using intraclass correlation coefficient (ICC), Pearson correlation coefficient and percent technical error of measurement (% TEM). Independent variables were age, systolic blood pressure, diastolic blood pressure, total cholesterol, high density lipoprotein (HDL) cholesterol, diabetes mellitus or impaired fasting glucose (vs. normoglycemics) and smoking (current vs. former and never). Multivariable linear regression analyses were performed to assess the independent associations of the individual risk factors with each RV parameter after adjustment for gender, ethnicity, height, and weight. In model 2, the corresponding LV parameter was added. A p value <0.05 was considered significant. Multiple interaction terms were introduced to evaluate the associations of each risk factor across different strata of age, gender and ethnicity; significance was declared at $p<0.004$ after applying Bonferroni correction for an average of 12 comparisons. To compare the association with the left ventricle parameters, similar multivariable analyses models were performed. Beta coefficients for the risk factors in each model as well as the percentage variability explained by the model (adjusted r^2) were determined. Analyses were repeated by including height squared or body surface area instead of height and weight as measures of body size. No significant change in beta coefficients were detected so height and weight adjusted models only are presented. All analyses were done using Stata Statistical Software release 10.0 (Stata Corp., College Station, Texas).

RESULTS

The MESA study included 6814 participants. 5098 participants were eligible and underwent cardiac MRI exam of which 4204 were randomly selected for right ventricle interpretation. Data on 30 participants ($<1\%$) were missing for one or more cardiovascular risk factor variables and were excluded from the study. Compared to those not included in the study ($n=2640$), the 4174 participants were on average slightly younger in age (61.4 vs. 63.3 years), had lower systolic blood pressure (125.5 vs. 128.4 mm Hg), lower body mass index (27.9 vs. 29.1 kg/m²), had a higher proportion of Chinese Americans (12.4% vs. 10.8%), lower proportion of

African-Americans (26.3% vs. 30.2%), were less likely to have hypertension (42.9% vs. 48.1%), less likely to be on hypertension medication (35.8% vs. 39.4%), less likely to have diabetes mellitus (11.7% vs. 14.1%), and more likely to be non smokers (51.6% vs. 48.5%), (all p values <0.05). The mean age of the 4174 participants included in this study was 61.4±10 years. 47.5% of the participants were men. 39.2% were Caucasian, 26.3% African-American, 22.1% Hispanic, and 12.4% were Chinese-American (table 1).

The mean values (± standard deviation) for the right ventricle parameters were 21.1g (±4.4) for mass, 124.2ml (±30.9) for EDV, 37.3ml (±14.2) for ESV, 86.8ml (±20.6) for SV and 70.4% (±6.5) for EF. Gender specific values for RV mass, volumes and ejection fraction are presented in table 2. Mean values of right ventricle mass and volumes were significantly higher in men as compared to women. Gender differences remained significant for all parameters even when indexed for body surface area (respective parameter divided by body surface area). RV ejection fraction was significantly lower in men as compared to women. With the sample sizes used in the present study, it was possible to detect gender differences in the RV parameters with a power greater than 90%.

Scans of 136 participants were included in the intra-reader reliability analyses and 154 were included in the inter-reader reliability analyses. The ICCs, Pearson correlation coefficients, and percent technical error of measurement (% TEM) are shown in table 3. All parameters had ICCs for both intra-reader and inter-reader reliability > 0.85, except for RVEF which was slightly lower (0.75 inter reader ICC).

The Pearson's correlation coefficients for RV mass, EDV, ESV, SV and EF with the corresponding LV parameter are shown in table 4. All RV parameters correlated positively with the LV parameters, ranging from 0.82 for end-diastolic volume to 0.47 for ejection fraction (all p values <0.0001).

The results from the multivariable linear regression models for RV mass, EDV and EF in relationship to cardiovascular risk factors are shown in table 5 both before (model 1) and after adjustment for the corresponding LV parameter (model 2). The proportion of variability explained by adding the LV to the multivariable model increased from 45 to 52% for RV mass, 52 to 74% for RV EDV and 15 to 28% for RV ejection fraction. Since the mean right and left ventricle masses were significantly different (21.1 g vs. 145.3g respectively), the percent change in RV and LV parameters in relationship to individual cardiovascular risk factors are shown in table 6.

Absolute RV mass showed an inverse relationship with age (−1.3g/10years, p<0.0001), which remained significant after adjusting for body size, demographic and cardiovascular risk factors (−1.0g/10 years, p<0.0001; table 5, model 1). After adjusting further for LV mass (model 2), the inverse association of RV mass with increasing age was nearly unchanged. Higher age was associated with a greater decrement in mass of the RV compared to the LV (−4.7% lower RV mass vs. −1.7% lower LV mass per 10 years, Table 6). Greater age was associated with lower RV EDV both before (−5.7 ml/10 years) and after (−1.6 ml/10 years) adjustment for LV EDV (models 1 and 2, Table 5). The decrease in RV EDV with age was greater than RV ESV (not shown), which led to a decrease in RV stroke volume with age. As a result, RV ejection fraction showed a modest increase as a function of age (+0.3% per 10 years, Table 5). The inverse relationship between age and RV EDV and ESV was slightly more prominent for men (−7.7ml/10 years & −3.0ml/10 years respectively vs. −4.0ml/10 years & 1.3ml/10 years for women). The associations between age and RV measures were similar across the different ethnic subgroups.

RV mass showed a small positive association with systolic blood pressure (+0.4g per 21mm Hg, p<0.00001) and a small inverse association with diastolic blood pressure (−0.3g per 10mm

Hg, $p<0.0001$) (table 5, model 1). After adjusting for LV mass (model 2), the relationship between RV mass was independent of systolic blood pressure but remained significant for diastolic blood pressure. Comparing the RV and LV response to cardiovascular risk factors (table 6), the percentage change in the RV mass was 1.9% versus 5.8% for LV mass per 21 mm Hg systolic blood pressure corresponding to a greater association of systolic blood pressure with the LV mass. The relationship between RV mass and systolic blood pressure was slightly more prominent in African Americans as compared to Caucasians (+0.5 g vs. +0.1g per 21 mm Hg; $p<0.0001$). RV EDV was positively related to systolic blood pressure (+1.6ml per 21mm Hg, $p<0.01$) and inversely with diastolic blood pressure (−2.2ml/10mm Hg, $p<0.0001$) (table 5, model 1). After adjusting for LV EDV (model 2), RV EDV was inversely related to systolic blood pressure and independent of diastolic blood pressure. The percentage change in RV EDV was 1.3% versus 4.2% for LV EDV in response to systolic blood pressure indicating a stronger association with LV EDV (table 6). RV EF was positively associated with systolic blood pressure (+1.0% per 21mm Hg, $p<0.0001$) and inversely with diastolic blood pressure (−0.7% per 10 mm Hg, $p<0.0001$) which remained significant even after adjusting for LV EF. The relationship between RV EDV, RV EF and blood pressure was similar across the different strata of age, ethnicity and gender.

RV mass and RV EDV were inversely related to total cholesterol (−0.2g per 35 mg/dl, $p<0.01$ & −1.4ml per 35 mg/dl, $p<0.0001$ respectively) (table 5, model1) which remained significant even after adjusting for the respective LV parameters (model 2). The relationship was similar across different subgroups of age, ethnicity and gender. RV mass and RV EDV showed a positive relationship with HDL cholesterol only in men (+0.5 g & +4.4ml respectively per 15 mg/dl, $p<0.0001$). After adjusting for LV, the relationship was significant only for RV mass. The relationship was similar across the different strata of age and ethnicity. The associations between cholesterol levels were similar for the RV and LV (table 6) with the exception of LV mass which was independent of HDL cholesterol. RVEF was positively associated with HDL cholesterol (+0.4% per 15 mg/dl $p<0.05$) which remained significant and unchanged even after adjusting for LVEF (table 5, model 1 and 2).

Current smokers had a lower RV EDV as compared to never smokers (−2.7ml, $p<0.05$) whereas RV mass and RV EF were independent of smoking status (table 5, model 1). When adjusted for the corresponding LV parameters (model 2), both RV mass and EDV were lower for current smokers as compared to never smokers.

RV mass and EDV showed an inverse association with impaired fasting glucose as compared with normoglycemic participants (−0.3g & −2.6ml respectively, $p<0.05$). After adjusting for the LV, the relationship was not significant for RV EDV. Comparing the percentage change in RV and LV (table 6), RVEDV was 2.1% lower in participants with impaired fasting glucose as compared to 3.6% lower LV EDV. Diabetes was associated with smaller RV EDV only in men (−5.1ml, $p<0.01$) but not after adjusting for LV EDV. RV mass and RV EF were not significantly associated with diabetes before or after adjusting for corresponding LV parameter.

DISCUSSION

In a cohort of participants free of clinical cardiovascular disease, cardiovascular risk factors were associated with changes in RV mass, volumes and ejection fraction detected with cardiac MRI. In particular, RV mass was approximately 20% lower in the oldest compared to the youngest decade participants. Additionally, higher systolic blood pressure and HDL cholesterol was associated with larger RV mass and volume whereas higher diastolic blood pressure and total cholesterol was associated with smaller RV mass and volume. Associations were similar for most risk factors across age, gender and ethnicity categories except for HDL which was associated with RV mass and EDV only in men, diabetes which was significantly

associated with RV EDV only in men and systolic blood pressure which showed more prominent association with RV mass in African-American participants as compared to the Caucasians. While most risk factors show a diminished association with RV parameters after adjusting for the LV, the relationship is nearly constant between age, HDL and RV mass.

The associations between the cardiovascular risk factors and the left ventricle have been previously studied in the MESA cohort ¹¹. The precise measurement of the right ventricular mass and volumes with MRI makes it possible to compare the relationship of these factors with the two chambers simultaneously. The right and left ventricle share the septal wall making them interdependent on one another functionally and structurally. LV filling depends on RV function; LV contraction contributes significantly to the RV function ^{12,13}. Furthermore, RV dysfunction adversely affects LV systolic function in select populations ¹⁴. It seems reasonable to believe that cardiovascular risk factors which are associated with changes in the LV might also influence the adjoining RV to a certain degree.

Aging was seen to be associated with lower RV and LV mass as well as corresponding volumes. Aging is associated with loss of cardiac myocytes ¹⁵, and our results suggest this process may be greater in the right than the left ventricle. The reasons for this are unknown. As expected, systolic blood pressure had a larger positive association with LV rather than RV mass and volume. Biventricular hypertrophy has been reported in response to systemic hypertension in prior studies ¹⁶. Echocardiography studies of RV function in hypertensive subjects has shown increased RV mass and diastolic dysfunction along with thickened interventricular septum and LV dysfunction ^{16,17}. The possible mechanism of RV modification could be due to increased pulmonary resistance as suggested by some studies ^{18,19}; response to growth factors such as aldosterone, angiotensin II, insulin like growth factors, catecholamines, endothelin, protoncogenes ^{20–23}; and functional interdependence to the pressure overload from the left ventricle ¹⁶. Acute and chronic effects of cigarette smoking show impaired RV and LV diastolic function in healthy participants ^{24–26}. In the MESA study, LV mass was higher in current smokers as compared to non smokers ¹¹. In the present study, only RV volume was significantly associated with smoking status. However, after adjusting for LV parameters, current smokers had both lower RV mass and volumes. Increased collagen deposition and atrial fibrosis has been shown to occur with cigarette smoking ²⁷. Smoking also leads to aging of the myocytes through oxidative stress ²⁸. Nicotine in cigarette smoke is toxic for cardiac fibroblasts which are responsible for maintaining extracellular matrix important for myocyte support and functioning ²⁹. It seems reasonable that the mechanisms by which the LV shows relatively increased mass while the RV shows decreased mass to smoking, which is evident only after adjusting for the changes in LV mass, may be mediated through different systemic and pulmonary vascular pathways, respectively.

The strengths of this study are that it includes a large adult population with a wide age range from different geographical locations with representation by multiple ethnic groups using cardiac MRI. This greatly improves the generalizability of our results to a broader population. Limitations of the study include a cross sectional design which did not allow for longitudinal study of the effects of the cardiovascular risk factors. The availability of newer steady-state free precession SSFP sequences allow better delineation of blood from myocardium than fast gradient echo sequence employed in the MESA study ³⁰. This study is limited to the inclusion of only asymptomatic cardiovascular disease-free population; the effects of cardiovascular risk factors could be different in individuals with existing cardiovascular disease.

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Table 1

Characteristics of the study population compared to those excluded. Numbers are presented as $\pm$ standard deviation or percentage as appropriate.

Parameter	Study sample (n=4174)	Excluded (n= 2640)
Age (years)	61.4 $\pm$ 10.1 *	63.3 $\pm$ 10.4
Male gender	47.5%	46.6%
Ethnicity		
White	39.2%	37.4%
Chinese American	12.4% *	10.8%
African American	26.3% *	30.2%
Hispanic	22.1%	21.6%
Height (cm)	166.4 $\pm$ 10.0	166.3 $\pm$ 10.2
Weight (kg)	77.4 $\pm$ 16.2 *	80.6 $\pm$ 18.9
Systolic blood pressure (mm Hg)	125.5 $\pm$ 21 *	128.4 $\pm$ 22
Diastolic blood pressure (mm Hg)	71.9 $\pm$ 10.2	72 $\pm$ 10.4
Total cholesterol (mg/dl)	194.3 $\pm$ 35.1	194.0 $\pm$ 36.8
High density lipoprotein cholesterol (mg/dl)	51.1 $\pm$ 15.0	50.7 $\pm$ 14.5
Hypertension	42.9% *	48.1%
Treated hypertension	35.8% *	39.4%
Diabetes mellitus (treated or untreated)	11.7% *	14.1%
Impaired fasting glucose	13.2%	14.8%
Cigarette smoking		
Current	12.6%	13.8%
Former	35.8%	37.7%
Never	51.6% *	48.5%
Body mass index (kg/m ²)	27.9 $\pm$ 5.0 *	29.1 $\pm$ 6.1

*
p<0.05

Table 2

Gender specific values for right ventricle mass, volumes and ejection fraction presented as means $\pm$ standard deviation.

Right ventricular parameters	Men (n=1995)	Women (n=2209)
Mass (g)	23.1 $\pm$ 4.4	19.2 $\pm$ 3.6 *
End Diastolic Volume (ml)	140.9 $\pm$ 29.6	109.1 $\pm$ 23.3 *
End Systolic Volume (ml)	45.1 $\pm$ 14.0	30.4 $\pm$ 10.2 *
Stroke Volume (ml)	95.8 $\pm$ 20.6	78.7 $\pm$ 16.8 *
Ejection Fraction (%)	68.2 $\pm$ 6.2	72.4 $\pm$ 6.0 *
Indexed for body surface area		
Mass (g/m ²)	11.7 $\pm$ 2.0	11.0 $\pm$ 1.7 *
End Diastolic Volume (ml/m ²)	71.5 $\pm$ 13.0	62.2 $\pm$ 10.6 *
End Systolic Volume (ml/m ²)	22.8 $\pm$ 6.5	17.3 $\pm$ 5.2 *
Stroke Volume (ml/m ²)	48.7 $\pm$ 9.4	44.9 $\pm$ 7.9 *

*
p<0.0001

Table 3

Intra class (ICC), Pearson Correlation Coefficients and Percent Technical Error of Measurement (% TEM) describing the Inter reader and Intra reader reproducibility for RV measures

Right ventricular parameter	INTER READER			INTRA READER		
	ICC	Pearson	% TEM	ICC	Pearson	% TEM
Mass (g)	0.87	0.78	10.9	0.93	0.87	7.1
End diastolic volume (ml)	0.96	0.92	7.5	0.99	0.98	3.7
End systolic volume (ml)	0.93	0.87	14.1	0.98	0.95	8.3
Stroke volume (ml)	0.92	0.85	10.3	0.97	0.95	5.3
Ejection fraction (%)	0.75	0.61	6.3	0.93	0.88	3.5

Table 4

Correlation coefficients between right and left ventricular parameters

Right Ventricle	Left Ventricle
Mass	0.62 [*]
End diastolic volume	0.82 [*]
End systolic volume	0.64 [*]
Stroke volume	0.79 [*]
Ejection fraction	0.47 [*]

^{*}
p<0.0001

Table 5

Multivariable analysis between right ventricular mass, end-diastolic volume and ejection fraction versus cardiovascular risk factors.

Proportion of variability explained by model (adjusted r^2)	RV Mass (g)		RV EDV (ml)		RV EF (%)	
	Model 1 45%	Model 2 52%	Model 1 52%	Model 2 74%	Model 1 15%	Model 2 28%
Age (per 10 years)	-1.0* (-1.2, -0.9)	-0.9* (-1.0, -0.8)	-5.7* (-6.5, -4.9)	-1.6* (-2.3, -1.0)	0.3 [†] (0.1, 0.5)	0.2 (0.0, 0.4)
Systolic blood pressure (per 21mm Hg)	0.4* (0.2, 0.5)	0.0 (-0.2, 0.1)	1.6 [†] (0.6, 2.6)	-1.6* (-2.4, -0.8)	1.0* (0.7, 1.3)	0.6* (0.4, 0.9)
Diastolic blood pressure (per 10 mm Hg)	-0.3* (-0.5, -0.2)	-0.3* (-0.5, -0.2)	-2.2 [†] (-3.2, -1.2)	0.1 (-0.9, 0.6)	-0.7* (-1.0, -0.5)	-0.3 [†] (-0.6, -0.1)
Current smokers (vs. never smokers)	-0.1 (-0.5, 0.2)	-0.5 [†] (-0.8, -0.2)	-2.7 [†] (-4.8, 0.6)	-3.1* (-4.6, -1.5)	-0.3 (-0.9, 0.3)	0.3 (-0.2, 0.9)
Total cholesterol (per 35 mg/dl)	-0.2 [†] (-0.3, -0.1)	-0.1 [‡] (-0.3, 0.0)	-1.4* (-2.1, -0.7)	-0.4 (-0.9, 0.1)	0.1 (0.0, 0.3)	0.1 (-0.1, 0.3)
High density lipoprotein (per 15 mg/dl)	0.2* (0.1, 0.4)	0.2 [†] (0.1, 0.3)	1.8* (1.1, 2.6)	0.3 (-0.3, 0.8)	0.4* (0.2, 0.6)	0.4* (0.2, 0.6)
Impaired fasting glucose (vs. normoglycemic)	-0.3 [†] (-0.7, 0.0)	-0.4 [‡] (-0.7, -0.1)	-2.6 [‡] (-4.6, -0.6)	0.1 (-1.4, 1.6)	0.4 (-0.2, 0.9)	0.4 (-0.1, 0.9)
Diabetes mellitus (vs. normoglycemic)	0.0 (-0.4, 0.3)	-0.2 (-0.5, 0.1)	-3.1 [†] (-5.2, -1.0)	-1.0 (-2.6, 0.6)	-0.2 (-0.8, 0.4)	0.2 (-0.4, 0.7)

* p<0.0001,

[†] p<0.01,

[‡] p<0.05

Model 1 is adjusted for ethnicity, gender, height and weight. Model 2 is further adjusted for the corresponding left ventricle parameter.

The mean difference in an individual right ventricular parameter is expressed as the beta coefficient and 95% confidence interval for the risk factor adjusted for all other covariates.

The beta coefficients were expressed in standard deviation units for continuous variables, for example, the mean increase in RV mass with systolic blood pressure is expressed per 21mm Hg.

Table 6

Percentage change in right and left ventricular mass and volumes associated with individual risk factors.

Risk factor	Right ventricle Mass	Left ventricle Mass	Right ventricle end diastolic volume	Left ventricle end diastolic volume
Age (per 10 years)	−4.7%	−1.7%	−4.6%	−5.4%
Systolic blood pressure (per 21 mm Hg)	1.9%	5.8%	1.3%	4.2%
Diastolic blood pressure (per 10 mm Hg)	−1.4%	NS	−1.8%	−2.8%
Current smokers (vs. never smokers)	NS	5.3%	−2.2%	NS
Total cholesterol (per 35 mg/dl)	−0.9%	−1.0%	−1.1%	−1.3%
High density lipoprotein (per 15 mg/dl)	0.9%	NS	1.4%	2.1%
Diabetes mellitus (vs. normoglycemic)	NS	2.8%	−2.5%	−2.8%
Impaired fasting glucose (vs. normoglycemic)	−1.4%	NS	−2.1%	−3.6%

NS: non-significant

Percentage change was calculated as: (Beta coefficient for the risk factor/mean value of the parameter) * 100