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Effect of Body Mass Index on Left Ventricular Mass in Career Male Firefighters

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Abstract

Left ventricular (LV) mass is a strong predictor of cardiovascular disease (CVD) events; increased LV mass is common among US firefighters and plays a major role in firefighter sudden cardiac death. We aim to identify significant predictors of LV mass among firefighters. Cross-sectional study of 400 career male firefighters selected by an enriched randomization strategy. Weighted analyses were performed based on the total number of risk factors per subject with inverse probability weighting. LV mass was assessed by echocardiography (ECHO) and cardiac magnetic resonance, and normalized (indexed) for height. CVD risk parameters included vital signs at rest, body mass index (BMI)–defined obesity, obstructive sleep apnea risk, low cardiorespiratory fitness, and physical activity. Linear regression models were performed. In multivariate analyses, BMI was the only consistent significant independent predictor of LV mass indexes (all, p <0.001). A 1-unit decrease in BMI was associated with 1-unit ($g/m^{1.7}$) reduction of LV mass/height$^{1.7}$ after

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adjustment for age, obstructive sleep apnea risk, and cardiorespiratory fitness. In conclusion, after height-indexing ECHO-measured and cardiac magnetic resonance–measured LV mass, BMI was found to be a major driver of LV mass among firefighters. Our findings taken together with previous research suggest that reducing obesity will improve CVD risk profiles and decrease on-duty CVD and sudden cardiac death events in the fire service. Our results may also support targeted noninvasive screening for LV hypertrophy with ECHO among obese firefighters.

Despite the critical prognostic significance of left ventricular (LV) mass,[1–3] its measurement and role in clinical practice have yet to be established.[4] Echocardiography (ECHO) and cardiac magnetic resonance (CMR) are the 2 most commonly used imaging methods for the assessment of LV mass. Although, CMR is considered the gold standard for assessing LV mass, ECHO is a well validated, noninvasive method that is more widely used in clinical practice.[5] In addition to considering different imaging methods, disagreement exists as to the most appropriate method of indexing LV mass to body size parameters.[3] Current evidence suggests indexing by height to the allometric powers of 1.7 and 2.7 are the most accurate normalization techniques.[4,6,7] This study identifies the most important predictors of LV mass after indexing for height among career male firefighters as assessed by both ECHO and CMR.

Methods

Male career firefighters, aged 18 years and older were recruited from the Indianapolis Fire Department. Eligible firefighters had a recorded fire department–sponsored medical examination in the last 2 years that included a submaximal exercise tolerance test and had no restrictions on duty.

From those eligible, we selected a total of 400 participants, using an “enriched” randomization strategy based on age at randomization, obesity, hypertension, and cardiorespiratory fitness status at last examination, where a larger number of higher risk participants could be selected. Thus, we randomly selected 100 participants from the entire eligible population; 75 low-risk participants (age <40, nonobese, free of hypertension, and high cardiorespiratory fitness) and 225 higher risk participants (at least 2 of the following: age ≥40 years, obese, hypertension, or low cardiorespiratory fitness) for further LV hypertrophy/cardiomegaly screening and imaging tests. Obesity was defined by standard criteria (body mass index [BMI] ≥30 kg/m^2). Hypertension was considered present if blood pressure at rest is ≥140/90 mm Hg. Low cardiorespiratory fitness was defined as the bottom tertile, as measured by the recorded treadmill time and the estimated maximal VO_2 during the last exercise test. Those selected were included in the study if they had no contraindication to CMR and signed informed consent to participate.

LV mass was assessed by both ECHO and CMR imaging. First, a transthoracic cardiac echocardiogram was done as a simple 2-dimensional study with limited m-mode recordings. An abbreviated CMR was performed as “function only” immediately after the ECHO. Images were obtained using a retrospectively electrocardiogram gated steady-state free precession cine sequence. In this fashion, a contiguous short-axis stack of 8-mm slices was obtained parallel to the atrioventricular groove to cover the entire length of the LV. Then, manual tracing of end-diastolic epicardial and endocardial borders was performed. Standard long-axis views were also obtained including horizontal long-axis, vertical long-axis, and 3-chamber views, facilitating the interpretation of ventricular function. Board certified specialists performed clinical interpretation of imaging. LV mass indexes were derived by dividing LV mass in grams with height to the allometric powers of 1.7 and 2.7 (in $meters^{1.7}$ and $meters^{2.7}$, respectively).

Height was measured in the standing position with a clinic stadiometer. Body weight was measured with bare feet and in light clothes on a calibrated scale. BMI was calculated as the weight in kilograms divided by the square of height in meters. Blood pressure was measured using an appropriately sized cuff with the subject in the seated position. Heart rate and blood pressure were obtained in a resting state from the physical examination (and were not measured before the exercise test). Medical examination data were further supplemented by a preimaging questionnaire, which collected comprehensive information on smoking status, a history of heart rhythm problems, family history of cardiac problems, and moderate to vigorous physical activity level in minutes per week. Obstructive sleep apnea risk was assessed using the validated Berlin Questionnaire.[8]

We performed a weighted analysis so as to account for our enriched randomization sampling strategy. Weights were calculated based on the total number of risk factors per subject with the technique of inverse probability weighting. Baseline characteristics were described using the mean (SD) in the case of quantitative variables and the frequency (%) for categorical variables. The effects of the different independent variables on the LV mass indexes were assessed with the use of linear regression models. Any independent variables that were significant in the univariate regression models were included in the multivariate regression models. In the multivariate analysis, we followed the backward stepwise elimination process with a removal criterion of alpha = 0.20. Then, considering the predictors that resulted from the backward elimination process and variables that we knew a priori to be important clinical predictors, we constructed the final multivariate regression models. The interaction effects between BMI with obstructive sleep apnea risk and age were also assessed in these models. Collinearity was evaluated using the variance inflation factor. Analyses were performed using SPSS, version 21.0 (IBM, Armonk, New York). A p value of <0.05 was considered statistically significant, and all tests performed were 2 sided.

Results

Of the 400 firefighters, we excluded 7 participants with missing measurements of LV mass, assessed by CMR. Baseline characteristics are summarized in Table 1. The mean age of the study subjects was 45 (8.1) years, their mean BMI was 30 (4.5) kg/m^2 and 45% were obese.

The univariate analyses summarized in Table 2 revealed highly statistically significant associations between both LV mass height indexes, assessed by both ECHO and CMR, with systolic blood pressure at rest, hypertension, high risk of obstructive sleep apnea, low cardiorespiratory fitness, and BMI (all $p <0.01$). Age, family history of cardiac problems, and physical activity also showed a significant association with both LV mass indexes, when LV mass was based on ECHO measurement (at least $p <0.01$).

In all 4 models evaluated, namely with LV mass assessed by ECHO or CMR and normalized with height to either 1.7 or 2.7, only BMI was consistently associated with LV mass in a statistically significant fashion ($p < 0.001$) in all multivariate models.

Final multivariate regression models showing the associations between the statistically and clinically significant predictors of LV mass are summarized in Table 3. A 1-unit decrease in BMI was associated with 1 unit ($g/m^{1.7}$) reduction of LV mass/height$^{1.7}$ after adjustment for age, obstructive sleep apnea risk, and cardiorespiratory fitness.

Discussion

The present cross-sectional study in US firefighters using ECHO and CMR measurements found BMI to be the strongest and most consistent independent predictor of LV mass indexed by height. In simple linear regression models, apart from BMI, the associations were highly statistically significant for high risk of obstructive sleep apnea, systolic blood pressure at rest, and low cardiorespiratory fitness consistently in all 4 models ($p < 0.01$). In multivariate models, however, BMI was the only consistently significant predictor. Therefore, our study clearly supported BMI as a major determinant of LV mass.

Given the epidemic level of obesity in the US fire service, it is not surprising that we found BMI to be the strongest predictor of LV mass in this population. This is consistent with the studies, which find obesity to be a risk factor for LV hypertrophy and increased cardiac mass.[9,10] In addition, given that obesity is associated with cardiovascular disease (CVD) risk factor clustering,[11,12] it probably explains why other factors such as blood pressure and obstructive sleep apnea risk were weaker predictors because of their association with LV mass may be closely linked to their association or co-morbidity with obesity.[13] Given our previous findings that obesity-associated sudden cardiac death (SCD) among younger firefighters was largely driven by an increased cardiac mass in SCD victims compared with controls,[14] our results reinforce that decreasing obesity in the fire service will lower the risk of LV hypertrophy and on-duty CVD events, particularly SCD. In agreement with findings that even small reductions on BMI may produce significant beneficial effects on metabolic syndrome and other CVD risk factors,[15,16] our results suggest that a 1-unit decrease in BMI will reduce LV mass index by 1 unit ($g/m^{1.7}$). Our results may also support targeted noninvasive screening for LV hypertrophy with ECHO among obese firefighters.

Based on the values of R^2 for our final multivariate regression models, we were able to explain 12.5% to 13.4% of the variability of LV mass indexed by height to the allometric powers of 1.7 and 2.7 based on ECHO assessments and 21.5% to 23.9% based on CMR assessments. We were able to explain 10% more of the LV mass variability with the CMR models compared with ECHO ones, irrespective of the indexation technique. This is likely explained by CMR measurements that are more standardized across techniques and institutions and less dependent on operator's skill and experience, acoustic window adequacy, and LV mass geometric assumptions.[3,17]

Our study has some modest limitations. Because of its cross-sectional design, we can only demonstrate associations and not causation; however, the findings are consistent with past studies[18] and are biologically plausible. In addition, because of the very small number of participating women firefighters in our study, only male participants were included in the present study.

Our study also has a number of important strengths. We were able to collect comprehensive data on CVD risk factors from both medical examinations and a screening questionnaire. The BMI was measured during medical examinations, which avoided self-reporting biases. Obstructive sleep apnea risk was assessed by the widely used and validated Berlin Questionnaire, which has high sensitivity and specificity (86% and 77%, respectively) and demonstrates a high yield in public safety occupations.[8,19] Moreover, we used imaging results for LV mass by both ECHO and CMR. Another important strength of our study is that we normalized LV mass by height to 2 different allometric powers, which allowed us to perform a more holistic assessment of its potential predictors. Furthermore, our results were consistent among the imaging methods and the indexing methods, making our findings more robust. Finally, our sample had similar anthropometric characteristics and CVD risk factors to those found in other epidemiologic studies of firefighters.[11,12,20] Therefore, we believe that our results could be generalized to most male career firefighters.

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Table 1

Baseline descriptive characteristics

Variables	Study Sample (N = 393)	Study Sample Unweighted
Age (years) *	47 ± 8.2	45 ± 8.1
Height (cm) *	179 ± 6.4	179 ± 6.6
Heart rate (bpm) *	81 ± 13	80 ± 13
Body weight (kg) *	99 ± 17	97 ± 17
Resting systolic blood pressure (mm Hg) *	126 ± 9.7	125 ± 9.4
Resting diastolic blood pressure (mm Hg) *	82 ± 8.1	81 ± 7.4
High risk of obstructive sleep apnea †	112 (38%)	254 (32%)
Body mass index (kg/m^2) *	31 ± 4.6	30 ± 4.5
Smoker †	50 (13%)	135 (13%)
History of heart rhythm problems †	60 (16%)	153 (15%)
Family history of cardiac problems †	153 (40%)	426 (41%)
Age ≥ 40 (years) †	301 (78%)	770 (73%)
Body mass index ≥ 30 (kg/m^2) †	260 (56%)	474 (45%)
Low cardiorespiratory fitness †	178 (47%)	363 (34%)
Moderate to vigorous physical activity (min/week) *	177 ± 117	187 ± 118
LV mass by echocardiography (g) *	189 ± 38	187 ± 37
LV mass by cardiac magnetic resonance (g) *	139 ± 24	138 ± 23
LV mass by echocardiography indexed to $height^{1.7}$ (g/$m^{1.7}$) *	70 ± 13	70 ± 13
LV mass by echocardiography indexed to $height^{2.7}$ (g/$m^{2.7}$) *	40 ± 7.6	39 ± 7.4
LV mass by cardiac magnetic resonance indexed to $height^{1.7}$ (g/$m^{1.7}$) *	52 ± 8.3	51 ± 8.1
LV mass by cardiac magnetic resonance indexed to $height^{2.7}$ (g/$m^{2.7}$) *	29 ± 4.7	29 ± 4.6

bpm = beats per minute; LV = left ventricular.

*Mean (SD) for continuous variables.

†n (%) for categorical variables.

Table 2

Simple linear regression models of cardiovascular risk factors and LV mass assessed by echocardiography and cardiac magnetic resonance and normalized for height to allometric powers of 1.7 and 2.7 as continuous variable

Variables	Assessed by ECHO				Assessed by CMR			
	Model 1*		Model 2†		Model 3*		Model 4†	
	β (SE)	P	β (SE)	p	β (SE)	p	β (SE)	p
Age (years)	0.11 (0.1)	0.02‡	0.10 (0.0)	<0.01‡	0.01 (0.1)	0.80	0.03 (0.0)	0.18
Heart Rate (bmp)	−0.01 (0.03)	0.78	−0.02 (0.0)	0.33	−0.02 (0.0)	0.34	−0.02 (0.0)	0.08
Resting systolic blood pressure (mmHg)	0.13 (0.04)	<0.01‡	0.08 (0.0)	<0.01‡	0.17 (0.0)	<0.01‡	0.10 (0.0)	<0.01‡
Resting diastolic blood pressure (mmHg)	−0.002 (0.1)	0.97	0.002 (0.0)	0.96	0.14 (0.1)	<0.01‡	0.08 (0.0)	<0.01‡
High risk of obstructive sleep apnea	5.64 (0.99)	<0.01‡	3.12 (0.6)	<0.01‡	3.90 (0.6)	<0.01‡	2.20 (0.3)	<0.01‡
Body Mass Index (kg/m^2)	0.95 (0.1)	<0.01‡	0.51 (0.1)	<0.01‡	0.86 (0.1)	<0.01‡	0.46 (0.0)	<0.01‡
Smoker	−2.62 (1.2)	0.03‡	−1.3 (0.7)	0.05‡	−1.11 (0.77)	0.15	−0.63 (0.4)	0.15
History of Heart Rhythm Problems	−2.68 (1.2)	0.02‡	−1.48 (0.6)	0.02‡	−0.98 (0.75)	0.19	−0.57 (0.4)	0.19
Family History of cardiac problems	3.26 (0.8)	<0.01‡	2.01 (0.5)	<0.01‡	0.07 (0.6)	0.89	0.24 (0.5)	0.44
Low cardiorespiratory fitness	3.24 (0.8)	<0.01‡	1.94 (0.5)	<0.01‡	1.53 (0.6)	<0.01‡	0.95 (0.3)	<0.01‡
Moderate to vigorous Physical Activity (min/week)	−0.02 (0.0)	<0.01‡	−0.01 (0.0)	<0.01‡	−0.002(0.0)	0.46	−0.001 (0.0)	0.28

bpm = beats per minute; CMR = cardiac magnetic resonance; ECHO = echocardiography.

*LV mass normalized for height to the allometric power of 1.7.

†LV mass normalized for height to the allometric power of 2.7.

‡Statistically significant p-values.

Table 3

Multivariate linear regression models of cardiovascular risk factors and LV mass assessed by echocardiography and cardiac magnetic resonance and normalized for height to allometric powers of 1.7 and 2.7 as continuous variable

	Assessed by ECHO				Assessed by CMR			
	Model 1*		Model 2†		Model 3*		Model 4†	
R^2	0.134		0.125		0.239		0.215	
	β (SE)	p	β (SE)	p	β (SE)	p	β (SE)	p
Age (years)	0.04 (0.1)	0.52	0.07 (0.0)	0.07	0.02 (0.0)	0.56	0.04 (0.0)	0.05
High risk of obstructive sleep apnea	0.76 (1.1)	0.49	0.36 (0.6)	0.57	0.15 (0.6)	0.81	0.11 (0.4)	0.76
Body Mass Index (kg/m^2)	1.01 (0.1)	<0.001‡	0.55 (0.1)	<0.001‡	0.83 (0.1)	<0.001‡	0.45 (0.0)	<0.001‡
Low cardiorespiratory fitness	−0.23 (1.0)	0.83	−0.34 (0.6)	0.57	−0.96 (0.6)	0.10	−0.70 (0.3)	0.05

CMR = cardiac magnetic resonance; ECHO = echocardiography.

*LV mass normalized for height to the allometric power of 1.7.

†LV mass normalized for height to the allometric power of 2.7.

‡Statistically significant p values.