Plasma Triglyceride Level is an Independent Predictor of Altered Left Ventricular Relaxation

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Background: Diastolic dysfunction, manifested by impaired left ventricular (LV) relaxation, is prevalent among individuals with metabolic disorders. The objective of this study was to evaluate the extent to which plasma triglyceride (TG) levels are related to LV diastolic function.

Methods: A total of 424 subjects (age 49 ± 12 years) had fasting plasma TG levels measured and underwent echocardiography for assessment of LV structure and function: LV ejection fraction and LV mass indexed to height (LVM/Ht$^{2.7}$); transmitral inflow early diastolic peak velocity (E wave) and late diastolic peak velocity (A wave), and E wave to A wave ratio (E/A); deceleration time; and Doppler tissue imaging early diastolic myocardial velocity (EM), an index of LV relaxation.

Results: All subjects had normal LV ejection fraction, 48% had hypertension, 16% had increased LVM/Ht$^{2.7}$, 11% had type 2 diabetes mellitus, 37% were obese, and 27% had hypertriglyceridemia (TG > 150 mg/dL). Univariate analysis showed significant relationships between TG level and E/A, deceleration time, and Em ($P \leq .001$ for all). After adjustment for potential confounders in multivariate models (eg, age, systolic blood pressure, and LVM/Ht$^{2.7}$), TG levels remained predictive of E/A, deceleration time, and Em ($P \leq .05$, $<.001$, and $\leq.0001$, respectively). Stepwise multivariate analysis showed that after age and body mass index, the TG level was the next most predictive variable of Em.

Conclusions: Plasma TG levels show a strong relationship with impaired LV relaxation, an early marker of diastolic dysfunction in human beings. These findings support a hypothesis whereby elevated TG levels favor myocyte intracellular lipid accumulation, possibly leading to lipotoxic diastolic dysfunction. (J Am Soc Echocardiogr 2005;18:1285-1291.)

Cardiovascular disease is a frequent manifestation of type 2 diabetes mellitus (T2DM), metabolic syndrome, obesity, and dyslipidemia, which frequently coexist in the same patients.[1,2] In patients with T2DM, left ventricular (LV) systolic dysfunction (LVSD) and LV diastolic dysfunction (LVDD) remain common, even after adjustment for comorbid conditions.[3-5] Insulin resistance, common not only in T2DM but in obesity and the metabolic syndrome, disrupts glucose uptake mechanisms, rendering the heart more heavily reliant on the oxidation of fatty acids for generating adenosine triphosphate.[6,7] Transgenic animal studies implicate alterations in cardiac energy metabolism, in particular increased myocardial fatty acid uptake and/or catabolism, as a primary mechanism in the pathophysiology of LVSD and LVDD.[8-13]

In T2DM, metabolic syndrome, obesity, or a combination of these, elevated plasma triglyceride (TG) levels are common, and this may lead to greater influx of fatty acids into myocytes. Clinical and epidemiologic studies have shown a high prevalence of LVDD in T2DM, even in the absence of overt cardiovascular disease.[14-17] However, the molecular mechanisms responsible for LVDD remain unknown. The current study tests the hypothesis that plasma TG levels are related to indices of LV diastolic function in human beings, and particularly to LV relaxation.

METHODS

Study Population

The cohort from which the study population was derived consisted of 578 consecutive ambulatory subjects 21 years

of age and older who participated in a cardiovascular genetics study at our institution. All study subjects underwent a complete cardiac evaluation, including: (1) history and physical examination; (2) measurements of blood pressure (BP)–diastolic and systolic BP (SBP) (obtained immediately before echocardiography after 10 minutes of rest in the sitting position and expressed as an average of 3 consecutive measurements in each arm); (3) fasting plasma glucose levels, serum insulin levels (collected only in those without diabetes), and plasma lipid profiles (obtained after a minimum 8-hour fast); and (4) complete 2-dimensional, Doppler, and Doppler tissue imaging (DTI) echocardiography.

Hypertriglyceridemia was defined as a plasma TG level greater than 150 mg/dL. Hypertension was defined as a BP of 140/90 mm Hg or higher, current medical therapy with an antihypertensive medication, or both. Diabetes was defined as a fasting plasma glucose level of 126 mg/dL or more, current medical therapy with an oral hypoglycemic agent or insulin, or both. Impaired fasting glucose was defined as a fasting plasma glucose of 100 or greater and less than 126 mg/dL in the absence of diabetes. Insulin resistance was defined as a fasting serum insulin level of 15 μU/dL or more in the absence of diabetes, impaired fasting glucose, or both. Obesity was defined as a body mass index (BMI) greater than 30 kg/m^2. The metabolic syndrome was diagnosed according to National Cholesterol Education Program's Adult Treatment Panel III guidelines, except that impaired fasting glucose was defined according to recommendations by the American Diabetes Association and endorsed by the American Heart Association and the National Heart, Lung, and Blood Institute's conference proceedings on the definition of the metabolic syndrome.[18-20]

Participants were excluded for one or more of the following: (1) pregnancy; (2) inadequate or incomplete echocardiograms; (3) LVSD (LV ejection fraction < 55%); (4) history of coronary artery disease, regional wall-motion abnormality on echocardiography, or both; (5) hypertrophic cardiomyopathy; (6) pulmonary hypertension (pulmonary arterial systolic pressure > 45 mm Hg); (7) significant valvular heart disease (stenosis or regurgitation > mild); (8) morbid obesity (BMI > 40 kg/m^2); or (9) other systemic illness (eg, plasma creatinine > 3.5 mg/dL, AIDS, malignancy, or autoimmune diseases). Thus, of the initial study cohort consisting of 578 consecutive individuals, 154 were excluded for the following reasons: 22 for incomplete echocardiogram; 46 for LVSD; 14 for known or suggested coronary artery disease (either a reported history or a regional wall-motion abnormality on echocardiography); 35 for morbid obesity (BMI > 40 kg/m^2); 9 for significant valvular heart disease (moderate or severe valvular regurgitation or stenosis); and 28 for missing plasma TG levels (primary end point), hypertrophic cardiomyopathy, systemic illnesses, or a combination of these. The resultant study population consisted of 424 subjects who met none of the exclusion criteria.

The study was approved by our human studies committee. Written informed consent was obtained from all study participants before study enrollment.

Imaging Protocol

The echocardiographic study was performed with a commercially available ultrasound system (Sequoia, Acuson-Siemens, Mountain View, Calif) and included 2-dimensional images, pulsed wave Doppler (PWD), and DTI. LV ejection fraction was calculated by the method of disks. LV mass was determined by the M-mode–derived cubed method and indexed to height$^{2.7}$ (LVM/Ht$^{2.7}$). The presence of LV hypertrophy was defined as LVM/Ht$^{2.7}$ greater than 2SD above the mean (ie, > 51 g/m$^{2.7}$ for men and > 49.5 g/m$^{2.7}$ for women).[21]

PWD-derived transmitral indices were recorded from the 4-chamber view at the mitral valve leaflet tips to determine the early diastolic (E wave) and atrial (A wave) velocities (m/s), the E/A wave velocity ratio, E-wave deceleration time (DT) (in milliseconds), and the isovolumic relaxation time (IVRT) (in milliseconds).[22] DTI-derived early diastolic myocardial velocity (Em) (in cm/s) was obtained at the septal mitral annulus from the apical 4-chamber view.[22-25] All reported measurements are the average of 3 consecutive cardiac cycles obtained by a single observer blinded to lipid status. An E/A ratio of 0.8 or less, Em less than 8.0 cm/s, or both were considered diagnostic of impaired LV relaxation.[26]

Statistical Analysis

All statistical analysis was performed using software (SAS, SAS Institute Inc, Release 9.1, Cary, NC). Continuous variables were reported as mean values ± SD. Between-group comparisons were performed by Student t test for normally distributed variables or the Wilcoxon rank score test for skewed variables. χ^2 analysis compared differences in proportions; the odds ratios (95% confidence intervals) were calculated of abnormal LV diastolic function (Em < 8.0 cm/s or E/A ≤ 0.8) occurring in individuals with hypertriglyceridemia (ie, TG > 150 mg/dL). Subjects were either assigned as having or not having T2DM for univariate and multivariate analyses based on a history of diabetes, fasting blood chemistries, or both. To further evaluate whether insulin resistance and/or glucose intolerance were independently associated with abnormal LV diastolic function, an alternate model used a 4-point ordinal scale, as follows: (1) normal; (2) insulin resistance; (3) impaired fasting glucose; or (4) diabetes.

Three analyses were performed to evaluate the relationship between TG levels and diastolic function: (1) univariate analyses between plasma TG and 4 echocardiographic indices of LVDD (Em, E/A, DT, and IVRT); (2) multivariate analyses modeling the 3 most important covariates identified from prior studies of LV diastolic function (age, LVM/Ht$^{2.7}$, and SBP); adjusted means (±SE) were reported; and (3) a comprehensive, stepwise multivariate model, using Em as the independent measure, where potential covariates included age, LVM/Ht$^{2.7}$, SBP, sex,

Table 1 Clinical characteristics of study population

	Entire population		
	Normal TG (n = 303)	**High TG** (n = 110)	***P* value**
Age, y	48 ± 12	51 ± 12	NS
Female, %	62	48	.006
Body mass index, kg/m^2	28 ± 5	31 ± 5	<.0001
Obesity, %	31	55	<.0001
HR, beats/min	64 ± 10	67 ± 11	.02
SBP, mm Hg	121 ± 17	127 ± 17	.001
DBP, mm Hg	78 ± 10	82 ± 8	.0002
Hypertension, %	46	55	NS
Plasma TG, mg/dL	87 ± 28	236 ± 118	<.0001
Metabolic syndrome, %	11	69	<.0001
Diabetes, %	8	21	.0001
	Non-diabetic population		
	(n = 284)	(n = 89)	
Plasma glucose, mg/dL	86 ± 11	88 ± 13	NS
Serum insulin, μU/dL	8.7 ± 9.0	13.4 ± 10.6	<.0001

DBP, Diastolic blood pressure; *HR,* heart rate; *NS,* not significant; *SBP,* systolic blood pressure; *TG,* triglycerides.

Table 2 Echocardiographic characteristics

Variable	**Normal TG** (n = 303)	**High TG** (n = 110)	***P* value**
LV ejection fraction, %	65 ± 5	64 ± 6	NS
LVM/Ht$^{2.7}$, g/m$^{2.7}$	40 ± 9	44 ± 10	.002
LVH*, %	15%	19%	NS
Em, cm/s	10.5 ± 2.8	9.2 ± 2.5	<.0001
E/A ratio	1.41 ± 0.53	1.25 ± 0.61	.0005
DT, ms	206 ± 38	221 ± 45	.005
IVRT, ms	96 ± 18	102 ± 20	.01

DT, Deceleration time; *E,* transmitral inflow early diastolic peak velocity; *Em,* Doppler tissue imaging-derived early diastolic myocardial velocity; *IVRT,* isovolumic relaxation time; *LV,* left ventricular; *LVH,* LV hypertrophy; *LVM/Ht$^{2.7}$,* LV mass indexed to height (g/m$^{2.7}$); *TG,* triglyceride level; *NS,* not significant.
*LVH defined as an LVM/Ht$^{2.7}$ > 51 g/m$^{2.7}$ for men, >49.5 g/m$^{2.7}$ for women.

race, BMI, heart rate, insulin resistance/diabetic status, and antihypertensive and/or lipid-lowering medication use. Variable entry into the model required a *P* value less than .15. Variables not normally distributed (TG, E/A, DT, and IVRT) were log-transformed for analysis. A *P* value less than .05 was considered statistically significant.

RESULTS

Population Characteristics

The study population consisted of 424 consecutive subjects (249 women; age 49 ± 12 years). Hypertriglyceridemia was present in 113 subjects (27%), hypertension in 204 (48%), insulin resistance in 37 (9%), impaired fasting glucose in 52 (13%), T2DM in 46 (11%), obesity in 157 (37%), and metabolic syndrome in 111 (26%). Based on the criteria defined in the methods section, 106 subjects (25%) did not meet criteria for hypertriglyceridemia, hypertension, insulin resistance, impaired fasting glucose, T2DM, obesity, or the metabolic syndrome.

Subjects were grouped according to the fasting TG levels into normal and high TG groups. Baseline characteristics of the two groups are listed in Table 1. Although the prevalence of hypertension was similar between groups, heart rate and BPs were significantly higher in the high TG group; the prevalence of T2DM and obesity were also higher in the high TG group compared with the normal TG group. Those in the high TG group were more likely to be taking angiotensin-converting enzyme inhibi-

tors (22% vs 12%, *P* = .01) and 3-hydroxy-3-methylglutaryl coenzyme A reductase inhibitors (22% vs 9%, *P* = .0003) than those in the normal TG group. There were no significant differences between groups in terms of other antihypertensive medication use including β-blockers, calcium channel blockers, angiotensin receptor blockers, adrenergic blockers, or thiazide diuretics (data not shown).

Echocardiographic Results

The echocardiographic results by groups are summarized in Table 2. Diastolic indices differed significantly between the groups: the high TG group had significantly lower Em and E/A ratio, and significantly longer DT and IVRT compared with the normal TG group. χ^2 analyses showed that the odds ratio (95% confidence intervals) of an individual in the high TG group was 2.6 (1.5-4.4) for having an abnormal Em and 2.2 (1.1-4.3) for having an abnormal PWD-derived mitral E/A ratio. Thus, hypertriglyceridemia is associated with abnormal indices of diastolic function.

Regression Analyses

Three analyses were performed to evaluate the relationship between TG levels and diastolic function. First, univariate analyses demonstrated significant inverse relationships between plasma TG and both Em and E/A, and significant positive relationships with DT and IVRT (Table 3). Second, multivariate analyses modeled the 3 most important covariates identified from prior studies of LV diastolic function (age, LVM/Ht$^{2.7}$, and SBP). Table 4 shows that after adjustment for these 3 covariates, TG continued to contribute significantly to the models predicting Em, E/A, and DT. The adjusted mean

Table 3 Univariate regression analyses (R^2)

	TG	Age	LVM/Ht$^{2.7}$	SBP
Em	.10*	.48*	.16*	.20*
E/A	.04*	.32*	.05*	.11*
DT	.04*	.10*	.03*	NS
IVRT	.03*	.24*	.07*	.09*

DT, Deceleration time; *E/A,* pulsed wave Doppler-derived E wave to A wave ratio; *Em,* Doppler tissue imaging-derived early diastolic myocardial velocity; *IVRT,* isovolumic relaxation time; *LVM/Ht$^{2.7}$,* left ventricular mass indexed to height (g/m$^{2.7}$); *NS,* nonsignificant; *SBP,* systolic blood pressure; *TG,* triglyceride level.
*$P \le .001$.

Table 4 Multivariate* regression analyses (R^2)

	TG and Age	TG & LVM/Ht$^{2.7}$	TG and SBP	TG, age, LVM/Ht$^{2.7}$, and SBP
Em	.53†	.22†	.26†	.57†
E/A	.33‡	.07‡	.13‡	.33§
DT	.13†	.06†	.05†	.13†
IVRT	.25§	.08‡	.10‡	NS

DT, Deceleration time; *E/A,* pulsed wave Doppler-derived E wave to A wave ratio; *Em,* Doppler tissue imaging-derived early diastolic mitral annular velocity; *IVRT,* isovolumic relaxation time; *LVM/Ht$^{2.7}$,* left ventricular mass indexed to height (g/m$^{2.7}$); *NS,* not significant; *SBP,* systolic blood pressure; *TG,* triglyceride level.
*P values for multivariate analysis reflect significance of TG in the model.
†$P \le .001$; ‡$P \le .01$; §$P < .05$.

($\pm$SE) of Em was 9.7 $\pm$ 0.2 and 10.4 $\pm$ 0.1 cm/s in the high and normal TG groups, respectively ($P = .001$). Third, a comprehensive, stepwise multivariate model was performed to address whether other variables also contribute significantly to LV diastolic function. These analyses, using Em as the independent measure, showed that after age and BMI, TG was the next most predictive variable ($P < .0001$), explaining a greater portion of the variance in Em than the remaining tested variables (sex, race, SBP, LV ejection fraction, LVM/Ht$^{2.7}$, T2DM status, and antihypertensive and lipid-lowering medication use). The model was unchanged when the 4-point ordinal scale of insulin resistance to T2DM was used (data not shown).

Analyses Limited to Cohort with Normal Glycemic/insulinemic Status

To further address whether the association between TG levels and Em was mediated by abnormalities in insulin sensitivity and/or glucose tolerance, the analyses were repeated only in those without a history of diabetes mellitus, whose plasma glucose and serum insulin levels were normal (see "Methods" section). For this cohort of 281 subjects (173 women; age 48 $\pm$ 13 years), hypertension was present in 116 (41%), hypertriglyceridemia in 51 (18%), obesity in 75 (27%), and metabolic syndrome in 27 (10%). As in the previous analyses, subjects were grouped

according to the plasma TG levels into normal and high TG groups. BP, BMI, and insulin levels were higher in the high TG group compared with the normal TG group. Although Em was not significantly different between the two groups ($P = .10$), the TG level remained predictive of Em in univariate analyses ($r^2 = .06$, $P \le .0001$). In the multivariate model adjusting for age, LVM/Ht$^{2.7}$, and SBP, the statistical significance remained ($r^2 = .53$, $P = .001$). The adjusted mean ($\pm$SE) of Em was 9.8 $\pm$ 0.3 and 10.6 $\pm$ 0.2 cm/s in the high and normal TG groups, respectively ($P = .01$). Stepwise multivariate analysis showed similar results as those in the original cohort.

DISCUSSION

This study shows that elevated plasma TG levels are associated with echocardiographic evidence of LVDD. The contribution of plasma TG levels to measures of LVDD was found to be independent of the effects of a number of variables, such as age, sex, race, LVM/Ht$^{2.7}$, SBP, T2DM status, and antihypertensive and lipid-lowering medication use, which are widely known to modulate LV diastolic function. Furthermore, the multivariate model indicates that the associations between TG levels and indices of LV diastolic function are independent of the attributable risk of insulin resistance and/or glucose intolerance, an observation that is further supported by analyses in a small cohort without diabetes and with normal insulin and glucose levels. In fact, in this smaller cohort, TG levels remained a significant predictor of DTI-derived Em velocity, a measure of LV relaxation. As discussed below and supported by studies in animal models of LVDD, this study supports a paradigm whereby the supply of lipid substrates to the myocardium significantly affects early diastolic function, possibly by favoring increased myocardial lipid uptake in excess of myocellular fatty acid oxidative capacity.

Under fasting conditions, fatty acid oxidation is the primary energy source of the normal mammalian adult heart, contributing approximately two-thirds of energy needs. However, the relative contribution of glucose use pathways to cardiac energy production is significant, allowing for a fuel use plasticity necessary for the maintenance of steady adenosine triphosphate production in the setting of a wide range of physiologic and/or dietary conditions.[27,28] Compared with glucose oxidation, fatty acid oxidation requires greater oxygen consumption/mol of substrate oxidized. Thus, an increased reliance on fatty acids for adenosine triphosphate production is associated with greater oxygen consumption.

Metabolic disorders characterized by increased levels of plasma TG and free fatty acids may promote

uptake of long-chain fatty acids in excess of tissue capacity for use. Animal models support a role for intracellular lipid accumulation in the pathogenesis of LVSD and LVDD.[8-13] Two distinct murine models associated with myocellular lipid accumulation (by overexpression of either a fatty acid transcription regulator or a fatty acid transport gene) are associated with LV hypertrophy, LVSD, or both.[8,9] In other models, increased production of toxic lipid intermediaries have been shown to trigger apoptotic pathways (ie, lipoapoptosis).[11-13] In these animal models, increased deposition of intracellular lipids has more commonly been associated with abnormal cellular function (ie, lipotoxicity), leading to LVDD and LVSD.[8-11]

In a leptin-deficiency–induced model of obesity (ob/ob mice), marked accumulation of intracellular lipids results in LV hypertrophy, decreased contractile reserve, and LVDD, as shown by the reversal of the PWD-derived mitral E/A ratio, but without evidence of systolic dysfunction.[10] Another animal model of obesity, a result of a leptin receptor mutation (ZDF fa/fa rat), showed that lipid accumulation preceded systolic dysfunction by 6 weeks, perhaps mirroring clinical studies that have shown that LVDD precedes systolic dysfunction by several decades in T2DM.[11,16,29] Collectively, these studies suggest a mechanism whereby mild intracellular lipid accumulation leads to abnormalities of LVDD, whereas marked intracellular lipid accumulation results in more severe phenotypes manifest by systolic dysfunction and/or apoptosis.

Animal studies have shown that cardiac lipoprotein lipase contributes significantly to myocellular lipid uptake.[30] In a transgenic mouse model where the human lipoprotein lipase gene was mutated to include a cell-attachment glycosylphosphatidylinositol anchor, cardiac-specific expression of the enzyme led to a dilated cardiomyopathy characterized by eccentric hypertrophy, decreased systolic function, and abnormal cytoarchitecture.[30] This phenotype was also accompanied by marked intracellular lipid accumulation, further supporting the hypothesis that intracellular lipid accumulation and/or excessive lipid oxidation results in myocardial systolic and/or diastolic dysfunction. The current study extends these recent findings from animal models into human beings by suggesting that myocyte intracellular lipid accumulation occurs with hypertriglyceridemia and contributes to LVDD.

Human beings with T2DM, metabolic syndrome, obesity, or a combination of these often have elevated plasma TG levels that likely lead to greater influx of fatty acids into myocytes. Invasive and noninvasive studies have reported an accumulation of lipid in the heart and skeletal muscle of individuals with T2DM, obesity, or both.[31,32] Thus, it appears that increased TG levels contribute to increased myocyte lipid accumulation and lipotoxicity. This is supported by a number of clinical studies linking abnormalities in myocardial lipid metabolism with alterations in LV structure and function.[14-16,33,34] T2DM studies show a high prevalence of LVDD.[14-16] Systolic and/or diastolic dysfunction coupled with decreased myocardial efficiency has been characterized in otherwise healthy, obese young women.[33,34] Myocardial fatty acid catabolism has also been shown to be a negative independent predictor of LV mass, and lower rates of myocardial fatty acid oxidation have been noted in patients with idiopathic dilated cardiomyopathy and in older healthy adults.[35-37] Collectively, these data provide strong circumstantial evidence that abnormalities in lipid metabolism may underlie the myocardial dysfunction of T2DM, obesity, metabolic syndrome, or a combination of these.

In this study, we found that TG levels were more predictive of DTI-derived Em velocity than any of the PWD-derived transmitral indices (ie, E/A, IVRT, DT). Unlike PWD-derived indices, Em is a relatively preload-independent measure of LV relaxation, a common abnormality characterizing early diastolic dysfunction.[22] As a result, DTI-derived Em velocity is a sensitive noninvasive measure of the early pathophysiologic changes that characterize the diastolic dysfunction in patients with hypertriglyceridemia.

Mechanisms whereby intracellular lipid accumulation may alter LV diastolic function include one or more of the following: (1) a relative state of energy depletion resulting from the favored oxidation of a less efficient fuel (ie, fatty acids) that compromises diastolic relaxation, an energy-dependent process; (2) increased intracellular lipid deposition leading to structural changes favoring LV hypertrophy, thus, resulting in secondary diastolic dysfunction; (3) accumulation of toxic lipid intermediaries and/or generation of reactive oxygen species leading to myocellular dysfunction and/or apoptosis; or (4) intracellular lipids disrupt excitation/contraction coupling by effects on ion channels. Further studies are needed to address the precise molecular mechanisms mediating the association between plasma TG levels and diastolic function.

Study Limitations

This study was designed to evaluate the relationship between plasma TG and LV diastolic function in an ambulatory population. As such, invasive hemodynamic measures were not clinically indicated. Echocardiography offers an acceptable noninvasive alternative for the assessment of diastolic function in clinical and animal studies. Subjects were excluded for known or suggested coronary artery disease based on history, the presence of wall-motion abnormalities on echocardiography, or both. Subjects did not undergo stress testing or coronary angiography

to exclude occult coronary artery disease. However, although it is possible that coronary artery disease may contribute to the incidence of LVDD, this would likely result in a small study effect. The duration of hypertriglyceridemia is unknown. Although a single fasting TG level may not accurately reflect the burden of hypertriglyceridemia over time, because the echocardiogram was performed simultaneously to this measurement, it is reasonable to assume that this TG measurement was representative of the metabolic milieu at the time of the study. Furthermore, in the absence of measured rates of myocardial fatty acid uptake and oxidation, plasma free fatty acid level measurements, or pathologic specimens for staining of lipids, the associations between plasma TG and LVDD remains speculative.

In summary, this study offers support for the emerging paradigm whereby intracellular deposition of lipids may contribute to myocardial dysfunction in dysmetabolic disorders, including T2DM, obesity, and the metabolic syndrome. Future clinical trials should investigate whether treatment of hypertriglyceridemia results in improved LV diastolic function.

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