Obstructive sleep apnoea and left ventricular diastolic dysfunction among first responders to the 9/11 World Trade Center terrorist attack: a cross-sectional study

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ABSTRACT
Objectives Obstructive sleep apnoea (OSA) is often linked to cardiovascular disease. A limited number of studies have reported an association between OSA and left ventricular diastolic dysfunction (LVDD). However, prior studies were performed on small patient populations. Studies have shown a high prevalence of OSA among first responders to the 9/11 World Trade Center (WTC) terrorist attack. We investigated the relationship between OSA and LVDD in a large population of WTC responders.

Design Cross-sectional study.

Setting One-time screening programme as part of the WTC-CHEST Study (NCT10466218), performed at a quaternary medical centre in New York City, from November 2011 to June 2014.

Participants A total of 1007 participants with mean age of 51 years of mostly non-Hispanic white men were evaluated. Patients from the WTC Health Program-Clinical Center of Excellence, who were over the age of 39 years, were eligible to participate.

Results Evaluation of those without OSA diagnosis showed no significant association with LVDD when comparing those screened (Berlin Questionnaire) as OSA high risk versus OSA low risk (p=0.101). Among those diagnosed with LVDD, there was a significant association when comparing those with and without patient-reported OSA (OR 1.50, 95% CI 1.13 to 2.00, p=0.005), but the significance was not maintained after adjusting for pertinent variables (OR 1.3, 94 to 1.75, p=0.119).

Notably, comparing those with OSA diagnosis and those low risk of OSA, the OR for LVDD was significant (1.69, 1.24 to 2.31, p=0.001), and after adjusting for waist–hip ratio, diabetes and coronary artery calcium score percentile, the relationship remained significant (OR 1.45, 1.03 to 2.04, p=0.032).

Conclusion The strong association of OSA with LVDD in this population may inform future guidelines to recommend screening for LVDD in high-risk asymptomatic patients with OSA.

INTRODUCTION
Obstructive sleep apnoea (OSA) is increasingly implicated in risk of cardiovascular disease (CVD) and stroke, particularly cardiometabolic risk (insulin resistance, atherogenic dyslipidaemia). Even in the presence of confounding factors, such as age, sex, obesity and dyslipidaemia, persuasive data associate OSA in the development of various CVDs, including hypertension, coronary artery disease (CAD), cerebrovascular disease, heart rhythm and conduction disorders. Among those affected with sleep apnoea, there is a very high prevalence of untreated OSA. Untreated OSA has a detrimental impact on health. The proposed pathophysiological mechanisms through which OSA can lead to cardiac dysfunction include increased sympathetic activity, endothelial dysfunction, systemic inflammation, oxidative stress and metabolic anomalies. A shared feature of cardiac dysfunction among patients with OSA is diastolic dysfunction, a term that refers to anomalies in the physiological characteristics of the diastolic phase of the cardiac cycle. It has been suggested that diastolic dysfunction falls into a spectrum, from mild to moderate to severe, progressively leading to heart failure with preserved ejection fraction (HfPef). HfPef is defined as the presence of the triad of...
impaired diastolic dysfunction, normal systolic function and symptoms of heart failure (HF). Although it is well recognised that patients with HF regardless of left ventricular (LV) ejection fraction (EF) have a worsened prognosis, less is known about the risk of asymptomatic diastolic dysfunction.

A limited number of small studies have consistently reported that patients with moderate-to-severe degree of OSA have a higher prevalence of left ventricular diastolic dysfunction (LVDD). LVDD is the impairment of the relaxation ability of the myocardium and the impairment of the LV to fill appropriately without increasing filling pressures. Although LVDD results from alterations in the relaxation and filling of the LV, the EF generally stays within normal range. LVDD may be among the early cardiac alterations occurring in patients with OSA, even before the development of hypertension or CVD.

On 11 September 2001, the destruction of the World Trade Center (WTC) resulted in inhalation of dust and chemicals to those at the site at the time of the disaster and for months following the incident. Now, two decades later, we are beginning to understand the long-term effects of this event on those who experienced it. Serious illness and injury following the attacks have affected thousands of responders who worked on the WTC rescue and recovery effort. Multiple studies have shown significant associations between severe OSA and WTC exposure.

The high prevalence of OSA among WTC responders makes this group a suitable population to assess the relationship between LVDD and OSA. To our knowledge, this is the first study to investigate the relationship between LVDD and OSA in a large population of WTC first responders.

METHODS

Study population

Participants of the Mount Sinai WTC Health Program-Clinical Center of Excellence, New York, New York, USA who were over the age of 39 years were eligible to participate in a one-time evaluation programme, WTC-CHEST (NCT10466218). Dissemination of the study was done by posting informational material at the WTC Health Program Clinics. A total of 1007 participants responded and were recruited from November 2011 to June 2014.

Patient and public involvement

Patients were not involved in the design, conduct, reporting or dissemination plans of this research.

Comprehensive cardiac evaluation

A one-time comprehensive cardiovascular evaluation of CVD risk, including the Framingham Risk Score, was performed on each participant. The evaluation included several components: (1) demographics and medical history questionnaire to determine CVD risk consisting of hypertension, diabetes, smoking and family history of premature coronary heart disease (CHD) as well as medication use and alcohol consumption; (2) exposure to the WTC cloud and subsequent clean up; (3) responses to validated questionnaires (Seattle Angina Questionnaire for chest pain, Dyspnea Questionnaire, Sexual Health Inventory for Men Questionnaire, Patient Health Questionnaire-9); (4) anthropometric measurements (waist circumference (WC), hip circumference, body mass index (BMI), systolic blood pressure (SBP), diastolic blood pressure (DBP)); (5) laboratory blood analysis: fasting glucose, fasting lipid panel (total cholesterol, high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), triglycerides (TG), high-sensitivity C reactive protein (hs-CRP), haemoglobin A1c (HbA1c)), serum creatinine, complete blood count and vitamin D levels. Coronary artery calcium score (CACS), which is a quantitative estimate of cardiovascular risk, was measured in a subset of 907 of the 1007 participants. Based on the Multi-Ethnic Study of Atherosclerosis, CACS percentile (CACS based on age, gender and race/ethnicity) greater than 75% was considered a CAD equivalent.

Sleep apnoea screening and assessment

Participants with no prior OSA diagnosis were screened for OSA risk. The Berlin Questionnaire (BQ) is the most widely used questionnaire to screen for OSA risk. High risk for OSA (OSA high risk) was defined as two or more positive categories on the BQ. Low risk for OSA (OSA low risk) was defined as those with less than two positive categories on the BQ. OSA diagnosis was defined as those who reported a physician diagnosis of OSA.

Echocardiography

Participants underwent comprehensive echocardiography including pulse-wave Doppler study to evaluate peak mitral inflow velocities at early (E) and late (A) diastole, transmitral E/A ratio and tissue Doppler imaging of the LV septum in the apical four-chamber view. Evaluation of LV diastolic function was performed according to the recommendations of the American Society of Echocardiography.

Statistical analysis

Analyses used SAS V.9.4, and p values of <0.05 were considered as significant. Continuous variables were summarised using their mean and SD, and analysed with either independent t-tests or analysis of variance, as appropriate. Variables with skewed distributions as determined by statistical testing underwent logarithmic transformation when warranted. Some continuous variables were dichotomised and/or categorised so as to analyse clinically meaningful differences. Dichotomous and categorical variables were analysed using X² or Fisher’s exact tests, as appropriate, and represented as frequencies and percentages. For the primary outcome, LVDD, logistic regression was used to obtain estimated ORs, both unadjusted and adjusted for waist–hip ratio, diabetes and CACS percentile.
### RESULTS

Baseline characteristics of the study population (n=1007) are shown in Table 1. Overall, the mean age was 51 years, mostly non-Hispanic white men. Twenty-eight per cent (282) were diagnosed with OSA, 27% (274) were OSA high risk and 45% (451) were OSA low risk. Those with OSA diagnosis and OSA high risk were more likely to be male and had a significantly higher prevalence of comorbidities compared with those who were OSA low risk. There were no significant differences in age, race/ethnicity, smoking, alcohol use and family history of premature CHD among the three groups. No significant valvular disease was seen in the cohort: one

|                  | Total population (n=1007) | No OSA diagnosis (n=451) | OSA low risk* (n=274) | OSA high risk* (n=282) | P value‡ |
|------------------|---------------------------|-------------------------|----------------------|-----------------------|---------|
| Age (years)      | 51.37±6.03                | 51.36±5.31              | 50.86±5.50           | 51.83±6.06            | 0.1671  |
| Gender–male (n (%)) | 841 (83.10)               | 346 (76.72)             | 239 (87.23)          | 251 (89.01)           | <0.0001 |
| Race (n (%))     |                           |                         |                      |                       | 0.5736  |
| 1=white          | 717 (70.85)               | 321 (71.18)             | 202 (73.72)          | 192 (68.09)           |         |
| 2=African American | 114 (11.26)              | 49 (10.86)              | 31 (11.31)           | 33 (11.70)            |         |
| 3=other§         | 181 (17.89)               | 81 (17.96)              | 41 (14.96)           | 57 (20.21)            |         |
| Ethnicity–Hispanic (n (%)) | 754 (74.73)             | 114 (25.28)             | 59 (21.53)           | 82 (29.18)            | 0.1170  |
| Ever smoked (n (%)) | 291 (28.93)              | 120 (26.67)             | 83 (30.40)           | 88 (31.43)            | 0.3243  |
| Cigarette use (n (%)) |                        |                         |                      |                       | 0.4533  |
| 0=never smoked   | 715 (71.07)               | 330 (73.33)             | 190 (69.60)          | 192 (68.57)           |         |
| 1=social smoker  | 23 (2.29)                 | 11 (2.44)               | 3 (1.10)             | 9 (3.21)              |         |
| 2=current smoker | 31 (3.08)                 | 13 (2.89)               | 8 (2.93)             | 10 (3.57)             |         |
| 3=ex-smoker      | 237 (23.56)               | 96 (21.33)              | 72 (26.37)           | 69 (24.64)            |         |
| Family history of premature CHD | 178 (17.62%)             | 89 (19.73%)             | 43 (15.69%)          | 45 (15.96%)           | 0.2685  |
| Hypertension¶    | 335 (33.17%)              | 84 (18.63%)             | 122 (44.53%)         | 128 (45.39%)          | <0.0001 |
| Hyperlipidaemia¶ | 379 (37.60%)              | 141 (31.26%)            | 116 (42.65%)         | 122 (43.26%)          | 0.0007  |
| Diabetes mellitus¶ | 85 (8.42%)                | 27 (5.99%)              | 25 (9.12%)           | 33 (11.74%)           | 0.0219  |
| Metabolic syndrome¶ | 341 (33.70%)             | 85 (18.85%)             | 113 (41.24%)         | 143 (50.71%)          | <0.0001 |
| GORD¶            | 462 (45.79%)              | 159 (35.25%)            | 115 (42.12%)         | 168 (66.67%)          | <0.0001 |
| Sinusitis¶       | 405 (40.10%)              | 136 (30.16%)            | 101 (36.86%)         | 168 (59.57%)          | <0.0001 |
| Asthma¶          | 250 (24.75%)              | 88 (19.41%)             | 58 (21.17%)          | 104 (36.88%)          | <0.0001 |
| RADS¶            | 81 (8.05%)                | 22 (4.88%)              | 16 (5.86%)           | 43 (15.41%)           | <0.0001 |
| Chronic bronchitis¶ | 101 (10.02%)             | 29 (6.44%)              | 21 (7.66%)           | 51 (18.15%)           | <0.0001 |
| Emphysema¶       | 12 (1.19%)                | 7 (1.55%)               | 1 (0.37%)            | 4 (1.42%)             | 0.0241  |
| COPD¶            | 106 (10.50%)              | 32 (7.10%)              | 21 (7.66%)           | 53 (18.79%)           | <0.0001 |
| CACS percentile >75% (n=907) | 242/907 (26.68%)         | 89/443 (22.08%)         | 52/196 (26.53%)      | 101/308 (32.79%)      | 0.0060  |
| WTC exposure (n (%)) |                        |                         |                      |                       | 0.0905  |
| Low              | 175 (17.34)               | 96 (21.29)              | 31 (14.49)           | 48 (13.95)            |         |
| Intermediate     | 498 (49.36)               | 210 (46.56)             | 113 (52.80)          | 175 (50.87)           |         |
| High             | 242 (23.98)               | 105 (23.28)             | 54 (25.23)           | 83 (24.13)            |         |
| Very high        | 94 (9.32)                 | 40 (8.87)               | 16 (7.48)            | 38 (11.05)            |         |

Continuous variables presented as mean. Categorical variables presented as number of patients (%).

*As defined by the Berlin Questionnaire.
†Patient-reported physician diagnosis.
‡Comparing the three OSA groups.
§Asian, American Indian/Alaska Native, Hawaiian/Pacific Islander.
¶Self-reported, on medication or medical chart documentation.
CACS, coronary artery calcium score; CHD, coronary heart disease; COPD, chronic obstructive pulmonary disease; GERD, gastro-oesophageal reflux disease; OSA, obstructive sleep apnoea; RADS, reactive airway dysfunction syndrome; WTC, World Trade Center.
patient had aortic stenosis and another had bicuspid aortic valve. Based on published WTC exposure scores, there was no significant difference in WTC dust exposure among all OSA groups.

Mean values of SBP, DBP and WC were significantly higher in OSA diagnosis and OSA high risk groups compared with OSA low risk group. Mean BMI was significantly higher in those diagnosed with OSA compared with those not diagnosed with OSA. Mean HDL-C was significantly higher in OSA low risk group separately compared with OSA high risk and OSA diagnosis groups. Mean value of TG was significantly lower in OSA low risk group separately compared with OSA high risk and OSA diagnosis groups. Mean HbA1c and hs-CRP were significantly higher in OSA diagnosis compared with OSA low risk group (table 2). SBP, DBP, WC and BMI as well as mean TG and blood glucose were significantly higher in those with LVDD compared with those without LVDD. Mean HDL-C was significantly higher in those without LVDD. There was no significant difference in mean total cholesterol, LDL-C, HbA1c and hs-CRP between those with and without LVDD (table 3). Echocardiographic indices of LV function according to OSA group are shown in table 4. Those with OSA diagnosis and OSA high risk were more likely to have increased LV mass (p<0.0001), and LV hypertrophy compared with those with OSA low risk (p<0.0001). Those with OSA diagnosis had significantly increased LV index compared with those with OSA low risk (p=0.0247). There was no significant difference in LV EF among the three groups. Diastolic function could not be evaluated in 64 of 1007 participants (6.3%) because of incomplete echocardiographic data. Of the remaining 943 participants, 52.7% (138 of 262) with OSA diagnosis had LVDD compared with 46.1% (119 of 258)

| Table 2 | Anthropometric and laboratory analyses of the WTC-CHEST Study population by OSA status |
|---------|---------------------------------|
|         | No OSA diagnosis                |
|         | OSA low risk*  | OSA high risk*  | OSA diagnosis†  | P value |
| (N=451) | (N=274)         | (N=282)         |               |
| Waist circumference (cm) | 96.27±12.60  | 105.84±11.63  | 107.85±13.61  | <0.0001† |
| Hip circumference (cm)   | 101.88±9.32  | 108.79±9.98   | 110.52±12.04  | <0.0001† |
| Waist:hip circumference ratio | 0.94±0.079  | 0.97±0.059    | 0.98±0.064    | <0.0001† |
| Body mass index (kg/m²)  | 27.84±3.91   | 31.54±4.30    | 32.45±5.27    | <0.0001† |
| Systolic blood pressure (mm Hg) | 116.15±12.05 | 120.32±10.37  | 119.47±11.01  | <0.0001† |
| Diastolic blood pressure (mm Hg) | 74.51±7.92  | 76.36±6.95    | 76.12±8.16    | 0.0055‡ |
| Total cholesterol (mg/dL) | 193.42±35.40 | 193.45±35.74  | 188.01±35.57  | 0.0952 |
| HDL-C (mg/dL)             | 58.94±17.72  | 52.58±12.87   | 50.39±13.18   | <0.0001† |
| LDL-C (mg/dL)             | 111.90±32.02 | 115.46±32.80  | 110.57±30.86  | 0.0969 |
| Triglyceride level (mg/dL) | 112.92±67.26 | 130.79±81.72  | 137.82±80.71  | 0.0060‡ |
| Blood glucose (mg/dL)     | 78.53±15.50  | 79.32±17.08   | 80.54±13.90   | 0.2354 |
| HbA1c (%)                 | 5.63±0.77    | 5.74±0.77     | 5.83±0.83     | 0.0023§ |
| hs-CRP (mg/L)             | 2.21±4.05    | 2.89±3.63     | 3.01±3.45     | 0.0169§ |

Continuous variables presented as mean. Categorical variables presented as number of patients (%).

*As defined by the Berlin Questionnaire.
†Patient-reported physician diagnosis.
‡Comparing OSA low risk and OSA high risk.
§Comparing OSA low risk and OSA diagnosis.
¶Comparing OSA high risk and OSA diagnosis.

HbA1c, haemoglobin A1c; HDL-C, high-density lipoprotein cholesterol; hs-CRP, high-sensitivity C reactive protein; LDL-C, low-density lipoprotein cholesterol; OSA, obstructive sleep apnoea; WTC, World Trade Center.
among OSA high risk, and 39.7% (168 of 423) among OSA low risk groups. There was a higher prevalence of LVDD in those with OSA diagnosis and OSA high risk compared with OSA low risk group (p=0.0038).

The associations of OSA diagnosis and OSA risk with LVDD are summarised in table 5. Those with OSA diagnosis had 1.50 times odds of having LVDD compared with those without OSA (p=0.0055). However, the association only trended towards significance after adjusting for confounding variables. Among those without OSA diagnosis, there was no significant association with LVDD when comparing OSA high risk and OSA low risk. Notably, the odds of having LVDD for those with OSA diagnosis were 1.69 times that of those who were OSA low risk (p=0.0010). Additionally, after adjusting for waist–hip ratio, diabetes and CACS percentile, the relationship remained significant (OR 1.45, 95% CI 1.03 to 2.04, p=0.0325). These results indicate a clear association between OSA and LVDD, independent of CAD.

**DISCUSSION**

There is still some degree of uncertainty about whether or not the association between OSA and LVDD is an independent one. Some of the most common risk factors for diastolic dysfunction, such as hypertension, ageing and diabetes, are also common features of patients with OSA. Notwithstanding differing results, most of the studies of patients with different cardiovascular profiles have found this association to be independent from other confounding factors, such as age, gender, BP, hypertension and BMI. However, a majority of these studies were carried out on small patient populations. The results of our study build up the evidence that OSA carries the risk of developing LVDD independent of these risk factors. Additionally, it was not known if the relationship between OSA and LVDD is dependent on CAD. In this study, the association remained significant after adjusting for CACS, which demonstrates that OSA is independently associated with LVDD irrespective of CAD status.

Recent studies have reported the increasing prevalence of OSA in men up to 30% and women 15% in North America. The prevalence and awareness of OSA risk have increased since the landmark study of the Wisconsin Sleep Cohort, and recently, the American Heart Association recommended OSA screening for patients with high-risk CVD (eg, those with poorly controlled hypertension, pulmonary hypertension and recurrent atrial fibrillation). However, routine screening for OSA is not part of general healthcare from the guidelines released by US Preventive Services Task Force (USPTF) of 2017. The USPTF group stated there is insufficient evidence to give guidelines for recommendations for OSA screening in asymptomatic adults. Results of this study may inform future guidelines to recommend OSA screening in high-risk asymptomatic patients and more importantly, screening for LVDD in patients with OSA. Diastolic dysfunction can be identified through routine echocardiography. Knowing the relationship between OSA and LVDD, it will be important to establish whether screening patients who are identified as high risk of OSA or those diagnosed with OSA would benefit from evaluation of LV function in order to initiate early intervention that can prevent the long-term consequences of CVD. This is particularly important as the prevalence of high-risk OSA in WTC responders is 36.6%.

### Table 3 Anthropometric and laboratory analyses of the WTC-CHEST Study population by LVDD status

|                      | LVDD–no (N=519) | LVDD–yes (N=426) | P value |
|----------------------|-----------------|-----------------|---------|
| Waist circumference (cm) | 39.66±5.81     | 40.93±4.89      | 0.0003  |
| Hip circumference (cm)   | 41.51±4.46      | 42.24±4.26      | 0.0106  |
| Waist:hip circumference ratio | 0.95±0.07    | 0.97±0.07       | <0.0001 |
| Body mass index (kg/m²)  | 29.82±5.09      | 30.68±4.73      | 0.0078  |
| Systolic blood pressure (mm Hg) | 116.8±11.15   | 120.1±11.5      | <0.0001 |
| Diastolic blood pressure (mm Hg) | 74.43±7.82  | 76.86±7.55      | <0.0001 |
| Total cholesterol (mg/dL) | 192.2±34.34     | 192.4±36.27     | 0.9260  |
| HDL-C (mg/dL)           | 56.38±17.25     | 52.47±13.12     | <0.0001 |
| LDL-C (mg/dL)           | 122.7±31.38     | 133.2±32.13     | 0.8138  |
| Triglyceride level (mg/dL) | 117.0±71.11    | 135.6±81.05     | 0.0002  |
| Blood glucose (mg/dL)   | 78.22±14.66     | 80.79±16.81     | 0.0136  |
| HbA1c (%)               | 5.68±0.80       | 5.76±0.80       | 0.1223  |
| hs-CRP (mg/L)           | 2.49±3.78       | 2.86±3.93       | 0.1411  |

Continuous variables presented as mean. Categorical variables presented as number of patients (%). HbA1c, haemoglobin A1c; HDL-C, high-density lipoprotein cholesterol; hs-CRP, high-sensitivity C reactive protein; LDL-C, low-density lipoprotein cholesterol; LVDD, left ventricular diastolic dysfunction; WTC, World Trade Center.
Limitations of the study include use of self-reported OSA diagnosis and use of BQ to assess for OSA risk. However, these methods were based on previous studies done in this cohort. Since the BQ takes into account BMI and history of hypertension, we did not adjust for it in our analysis but used waist–hip ratio that has been shown to have a strong association with sleep apnoea. The findings would be more robust if sleep study data were available to provide evaluation of OSA severity and LVDD. Moreover, this study is focused on a single population that is largely male and Caucasian, and the relationships we find here between OSA and LVDD may not be generalisable to a more diverse population. Additionally, this population was exposed to environmental factors in

**Table 4**  Echocardiographic indices of LV function according to OSA group

|                        | No OSA diagnosis | OSA high risk* | OSA diagnosis† | P value |
|------------------------|------------------|----------------|----------------|---------|
| N                      | 451 (423‡)       | 274 (258‡)     | 282 (262‡)     | 0.4515  |
| EF (%)                 | 61.28±5.23       | 61.64±5.34     | 61.76±5.61     | 0.2141  |
| E/A (continuous)       | 1.11±0.35        | 1.10±0.52      | 1.04±0.60      | 0.0033  |
| E/e′ (continuous)      | 7.63±2.39        | 8.76±5.53      | 8.42±2.84      | 0.0177  |
| e′/a′ (continuous)     | 0.87±0.59        | 0.77±0.25      | 0.78±0.40      | 0.0361  |
| LV mass                | 184.69±149.92    | 171.08±39.70   | 153.84±38.44   | 0.2635  |
| LV index               | 76.12±16.19      | 79.16±16.31    | 84.72±74.05    | 0.0197  |
| LVPW thickness–abnormal (n (%))‡ | 86 (19.07) | 80 (29.20)     | 105 (37.23)    | <0.0001 |
| LV septal thickness–abnormal (n (%))‡ | 188 (41.68) | 156 (56.93)    | 167 (59.22)    | <0.0001 |
| RWT–abnormal (n (%))‡  | 151 (33.48)      | 112 (40.88)    | 147 (52.13)    | <0.0001 |
| LV geometry (n (%))‡  | 292 (64.75)      | 156 (56.93)    | 132 (46.81)    | <0.0001 |
| 0=normal geometry      | 148 (32.82)      | 107 (39.05)    | 139 (49.29)    |          |
| 1=concentric remodelling| 8 (1.77)        | 6 (2.19)       | 3 (1.06)       |          |
| 2=eccentric hypertrophy| 3 (0.67)        | 5 (1.82)       | 8 (2.84)       |          |
| Diastolic dysfunction–yes (n (%))‡ | 168 (39.72) | 119 (46.12)    | 138 (52.67)    | 0.0038  |

Continuous variables presented as means. Categorical variables presented as number of patients (%).

*As defined by the Berlin Questionnaire.
†Patient-reported physician diagnosis.
‡Sixty-four participants with missing echocardiographic indices for diastolic function.
§Comparing OSA low risk and OSA high risk.
¶Comparing OSA low risk and OSA diagnosis.

EF, ejection fraction; FE, Fisher’s exact; LV, left ventricular; LVPW, LV posterior wall; OSA, obstructive sleep apnoea; RWT, relative wall thickness.

**Table 5**  Association of OSA diagnosis and OSA risk with left ventricular diastolic dysfunction

|                        | OR     | 95% CI             | P value |
|------------------------|--------|-------------------|---------|
| OSA diagnosis vs no OSA diagnosis* | Unadjusted | 1.499 | 1.126 to 1.996 | 0.0055 |
|                        | Adjusted† | 1.281 | 0.938 to 1.749 | 0.1191 |
| OSA high risk vs OSA low risk on the BQ‡ | Unadjusted | 1.299 | 0.950 to 1.777 | 0.1007 |
|                        | Adjusted† | 1.272 | 0.910 to 1.779 | 0.1596 |
| OSA diagnosis* vs low risk on the BQ‡ | Unadjusted | 1.689 | 1.238 to 2.306 | 0.0010 |
|                        | Adjusted† | 1.452 | 1.032 to 2.044 | 0.0325 |

*Patient-reported physician diagnosis.
†Adjusted ORs were obtained after controlling for waist–hip ratio, diabetes and coronary calcium score percentile.
‡As defined by the BQ.

BQ, Berlin Questionnaire; OSA, obstructive sleep apnoea.
an acute fashion, which is only less commonly observed in the general population. Hence, it will be important to determine other cardiovascular pathophysiological changes that may be associated with OSA in the WTC first responders. However, studies are now showing that climate change can affect air quality leading to elevated levels of particulates in the environment. It is reasonable to consider if such events can increase OSA and also lead to LVDD. Further studies are needed to define the relationship between OSA and LVDD in diverse populations under diverse exposure conditions. As this study demonstrates, while controlling for pertinent variables, there is a strong relationship between OSA and LVDD.

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