Published in final edited form as:

Environ Res. 2017 April ; 154: 115–119. doi:10.1016/j.envres.2016.12.031.

Fine Particulate Air Pollution and Premature Ventricular Contractions: The REasons for Geographic And Racial Differences in Stroke (REGARDS) Study

Wesley T. O'Neal^{1,*}, Elsayed Z. Soliman^{2,3}, Jimmy T. Efird⁴, Virginia J. Howard⁵, George Howard⁶, and Leslie A. McClure⁷

¹Department of Medicine, Division of Cardiology, Emory University School of Medicine, Atlanta, GA, USA

²Department of Medicine, Section on Cardiology, Wake Forest School of Medicine, Winston-Salem, NC

³Epidemiological Cardiology Research Center (EPICARE), Department of Epidemiology and Prevention, Wake Forest School of Medicine, Winston-Salem, NC

⁴Department of Cardiovascular Sciences, East Carolina Heart Institute, Brody School of Medicine, East Carolina University, Greenville, NC

⁵Department of Epidemiology, School of Public Health, University of Alabama at Birmingham, Birmingham, AL

⁶Department of Biostatistics, School of Public Health, University of Alabama at Birmingham, Birmingham, AL

⁷Department of Epidemiology and Biostatistics, Dornsife School of Public Health, Drexel University, Philadelphia, PA

Abstract

Background—It is unknown if higher levels of ambient particulate matter (PM) exposure increase the risk for premature ventricular contractions (PVC) in a population-based study of men and women, and if this relationship varies by race or sex.

Methods—We examined the association of PM <2.5 micrometers in diameter (PM_{2.5}) concentration with PVCs in 26,121 (mean age=64 ± 9.3 years; 55% female; 41% black) participants from the REasons for Geographic And Racial Differences in Stroke (REGARDS)

* **Correspondence to:** Department of Medicine, Division of Cardiology, Emory University School of Medicine, 101 Woodruff Circle Woodruff Memorial Building Atlanta, GA 30322. Tel.: +1.404.727.2273. wesley.oneal@emory.edu.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

INFORMED CONSENT

All participants provided written informed consent and the study was approved by all participating institutional review boards.

study. Estimates of short- (2-week) and long-term (1-year) PM_{2.5} exposures were computed prior to the baseline visit using geographic information system data on the individual level at the coordinates of study participants' residences. PVCs were identified from baseline electrocardiograms.

Results—PVCs were detected in 1,719 (6.6%) study participants. Short- (OR=1.08, 95%CI=1.03, 1.14) and long- (OR=1.06, 95%CI=1.01, 1.12) term PM_{2.5} exposures were associated with PVCs. Interactions were not detected by race or sex. An interaction between short-term PM_{2.5} exposure and PVCs was detected for those with cardiovascular disease (OR=1.16, 95%CI=1.06, 1.27) compared with those without cardiovascular disease (OR=1.05, 95%CI=0.99, 1.12; p-interaction=0.027).

Conclusion—Our findings suggest that PM_{2.5} exposure is associated with an increased risk for PVCs in a biracial population-based study of men and women. We also have identified persons with cardiovascular disease as an at-risk population for PVCs when increases in short-term PM_{2.5} concentration occur.

Keywords

particulate matter; ventricular ectopy; epidemiology

INTRODUCTION

Exposure to ambient particulate matter (PM) has been associated with various cardiovascular outcomes, including the development of high blood pressure, atherosclerosis, myocardial infarction, and vascular dysfunction (Auchincloss et al., 2008; Brook et al., 2004; Diez Roux et al., 2008; Krishnan et al., 2012; Miller et al., 2007; Park et al., 2010; Pope et al., 2015; Rosenlund et al., 2006). Several reports also have suggested that PM exposure increases the risk for ventricular arrhythmias. This is supported by data that have linked short-term (24-hour) PM exposure with ventricular arrhythmias (ventricular tachycardia and ventricular fibrillation) in patients with implantable cardioverter-defibrillators (ICD) (Dockery et al., 2005; Rich et al., 2005). PM exposure also has been associated with an increased risk for premature ventricular contractions (PVCs) among persons with coronary heart disease (Bartell et al., 2013; Berger et al., 2006), and among women who smoke (Liao et al., 2009).

The findings of the above studies were limited in generalizability, as they were conducted in specific populations (e.g., patients with ICDs, coronary heart disease, and women). Currently, it is unknown if higher levels of ambient PM exposure increase the risk for PVCs in a population-based study of men and women, and if this relationship varies by race or sex. Therefore, the purpose of this study was to examine the associations of PM exposure (short- and long-term) with PVCs in the REasons for Geographic And Racial Differences in Stroke (REGARDS) study.

METHODS

Study Population and Design

Details of REGARDS have been published previously (Howard et al., 2005). Briefly, REGARDS is a prospective cohort study designed to identify causes of regional and racial disparities in stroke mortality. The study over-sampled blacks and persons residing in the stroke belt (North Carolina, South Carolina, Georgia, Alabama, Mississippi, Tennessee, Arkansas, and Louisiana) between January 2003 and October 2007. This included participants from the stroke buckle (coastal plains of North Carolina, South Carolina and Georgia), as this region experiences a stroke mortality rate considerably higher than the rest of the United States (Howard et al., 1997). A total of 30,239 participants were recruited from a commercially available list of residents using postal mailings and telephone data. Demographic information and medical histories were obtained using a computer-assisted telephone interview (CATI) that was conducted by trained interviewers. Additionally, a brief in-home physical examination was performed 3 to 4 weeks after the telephone interview. During the in-home visit, trained staff collected information regarding medications, blood and urine samples, and a resting electrocardiogram. All participants provided written informed consent and the study was approved by all participating institutional review boards. For the purpose of this analysis, participants were excluded if they were missing PM exposure or baseline covariate data. Additionally, participants who had evidence of atrial fibrillation or premature atrial contractions were excluded.

PM_{2.5} Exposure

PM_{2.5} particles are air pollutants with an aerodynamic diameter less than 2.5 micrometers and measures are in micrograms per cubic meter ($\mu\text{g}/\text{m}^3$). Spatial surfaces of estimated PM_{2.5} exposures on a 10-km grid were generated using United States Environmental Protection Agency (EPA) ground observation data and National Aeronautics and Space Administration's (NASA) MODerate-resolution Imaging Spectroradiometer (MODIS) data between 2003 and 2008. Estimates were spatially linked with REGARDS participants using geographic information system (GIS) data on the individual level at the geographic coordinates of study participants' residences. Short-term PM_{2.5} exposure was computed as the 2-week average value prior to the baseline visit, and long-term exposure was computed as the 1-year average value prior to the baseline visit. Details of the methods used to compute PM_{2.5} exposure and linkage with REGARDS participants have been reported (Al-Hamdan et al., 2014; Al-Hamdan et al., 2009).

Data from the NASA product of the North American Land Data Assimilation System Phase 2 (NLDAS-2) forcing dataset were used to determine 2-week and 1-year temperature averages prior to the baseline visit. This NLDAS-2 product is based on model re-analysis data, as well as remotely-sensed and ground observations, and consists of a grid surface with ~14 km resolution over North America (Cosgrove et al., 2003).

Premature Ventricular Contractions

Electrocardiograms of study participants were read centrally at the Epidemiological Cardiology Research Center (EPICARE) located at the Wake Forest School of Medicine

(Winston-Salem, NC) by trained electrocardiographers who were blinded to study outcomes. Trained staff performed visual inspection for technical errors and inadequate quality. Electrocardiograms that were considered of poor quality were not included. PVCs were ascertained from baseline electrocardiograms using Minnesota code criteria (8.1.2, 8.1.3, 8.1.5, 8.2.2, 8.2.3) (Prineas et al., 2010). Participants with sustained ventricular rhythm disorders, such as sustained ventricular tachycardia (e.g., cases >30 seconds), were not included in our analysis. The first 8,330 REGARDS participants underwent 7-lead electrocardiogram recording. However, during the course of the study, it was felt that 12-lead electrocardiograms should be used. Accordingly, the rest of REGARDS participants underwent a standard 12-lead recording. PVCs were ascertained from both 7- and 12-lead electrocardiograms (Soliman et al., 2010). The different ECG recordings (7- and 12-lead) did not impact the ability to detect PVCs because the same duration was used for both tracings.

Covariates

Age, sex, race, income, education, and smoking status were self-reported. Income was dichotomized at \$20,000. Education was categorized into “high school or less,” or “some college or more.” Smoking was defined as self-reported current cigarette use. Fasting blood samples were obtained and assayed for high-density lipoprotein cholesterol, total cholesterol, and serum glucose. Diabetes was defined as a fasting glucose level ≥ 126 mg/dL (or a non-fasting glucose ≥ 200 mg/dL among those failing to fast) or self-reported diabetes medication use. The current use of aspirin, antihypertensive medications, and lipid-lowering therapies was self-reported. After the participant rested for 5 minutes in a seated position, blood pressure was measured using a sphygmomanometer. Two values were obtained following a standardized protocol and averaged. Body mass index was computed as the weight in kilograms divided by the square of the height in meters. Using baseline electrocardiogram data, left ventricular hypertrophy was defined by the Sokolow-Lyon Criteria (Sokolow and Lyon, 1949). Coronary heart disease was ascertained by self-reported history of myocardial infarction, coronary artery bypass grafting, coronary angioplasty or stenting, or if evidence of prior myocardial infarction was present on the baseline electrocardiogram. Prior stroke was ascertained by participant self-reported history. Cardiovascular disease was defined as the composite of coronary heart disease and stroke.

Statistical Analyses

Baseline characteristics were compared by the presence of PVCs. Categorical variables were reported as frequency and percentage while continuous variables were reported as mean $\pm$ standard deviation (SD). Statistical significance for categorical variables was tested using the chi-square method and the student's t-test procedure for continuous variables. Logistic regression was used to compute odds ratios (OR) and 95% confidence intervals (CI) for the associations of short- and long-term PM_{2.5} exposures with PVCs, separately. The association was examined per 1-SD increase ($\mu\text{g}/\text{m}^3$) in PM_{2.5} concentration (short-term: SD=4.07 $\mu\text{g}/\text{m}^3$; long-term: SD=1.93 $\mu\text{g}/\text{m}^3$). Multivariable models were adjusted as follows: Model 1 adjusted for age, sex, race, education, income, geographic region, and average temperature (2-week average for short-term and 1-year average for long-term); Model 2 included Model 1 covariates, with the addition of systolic blood pressure, high-density lipoprotein

cholesterol, total cholesterol, body mass index, smoking, diabetes, antihypertensive medications, lipid-lowering therapies, left ventricular hypertrophy, and prior history of cardiovascular disease. Additionally, subgroup analyses were performed to evaluate effect modification by age (<65 years vs. ≥65 years), race (black vs. white), sex, and cardiovascular disease using a stratification technique and comparing interaction terms in Model 2. Statistical significance for all comparisons including interactions was defined as $p < 0.05$. SAS[®] Version 9.4 (Cary, NC) was used for all analyses.

RESULTS

A total of 26,121 (mean age=64 ± 9.3 years; 55% female; 41% black) participants were included in this analysis. PVCs were detected in 1,719 (6.6%) of study participants. A higher 1-year average PM_{2.5} concentration was observed for those with PVCs compared with those without PVCs. No difference was observed between the mean 2-week PM_{2.5} concentration for those with and without PVCs (Table 1). Baseline characteristics stratified by the presence of PVCs are shown in Table 1.

The results for short- and long-term PM_{2.5} exposures are shown in Tables 2 and 3, respectively. Short- and long-term PM_{2.5} exposures were both associated with PVCs. The likelihood of PVC increased by 8% for each 1-SD increase in short-term PM_{2.5} exposure (95%CI= 3%, 14%) after multivariable adjustment. The likelihood of PVC increased by 6%(95%CI=1%, 12%) for each 1-SD increase in long-term PM_{2.5} exposure.

The association between short-term PM_{2.5} exposure and PVCs was modified by the presence of cardiovascular disease (p -interaction=0.027) (Table 2). A significant association between short-term PM_{2.5} exposure and PVCs was observed among participants with cardiovascular disease (OR=1.16, 95%CI=1.06, 1.27). In contrast, the relationship between short-term PM_{2.5} exposure and PVCs was not significant in participants without cardiovascular disease (OR=1.05, 95%CI=0.99, 1.12). Interactions were not detected by age, race, or sex, for short-term PM_{2.5} exposure (Table 2). Additionally, no interactions were detected by age, race, sex, or cardiovascular disease for long-term PM_{2.5} exposure (Table 3).

DISCUSSION

In this analysis from REGARDS, short- and long-term PM_{2.5} exposures were associated with an increased risk for PVCs in a biracial population-based study of men and women. The relationship between PM_{2.5} exposure and PVCs did not depend on race or sex. Additionally, we identified persons with cardiovascular disease as an at-risk population for PVCs when PM_{2.5} levels acutely rise.

Several reports have linked PM exposure with ventricular arrhythmias. An examination of 204 congestive heart failure patients with ICDs observed an increased risk (OR=1.19, 95%CI=1.02, 1.38) for ventricular arrhythmias (ventricular tachycardia and ventricular fibrillation) with each 7.8 µg/m³ increase in the mean PM_{2.5} concentration over the 24 hours prior to the arrhythmic event (Rich et al., 2005). Another examination of the same cohort showed a positive association between the mean 2-day PM_{2.5} concentration (OR=1.08, 95%CI=0.96, 1.22) and ventricular tachyarrhythmias, and they reported that the relationship

was related to prior arrhythmic events occurring within 3 days (<3 days: OR=1.60, 95%CI=1.30, 95%CI=1.96; >3 days: OR=0.98, 95%CI=0.86, 1.12; p-interaction <0.001) (Dockery et al., 2005). Additionally, studies of patients with coronary heart disease observed an increased risk for PVCs with increases in PM_{2.5} concentration (Bartell et al., 2013; Berger et al., 2006). An examination of 105 middle-age community-dwelling healthy nonsmokers in central Pennsylvania also showed that PM_{2.5} concentration increases (per 10 $\mu\text{g}/\text{m}^3$) were associated with an 8% increase in average PVC counts during 30 minutes of Holter monitoring (He et al., 2011). Furthermore, a sample of 57,422 participants from the Women's Health Initiative study showed that among current smokers, acute PM_{2.5} concentrations were significantly associated with PVCs, but similar results were not observed for non-smokers (Liao et al., 2009).

The results of the current analysis confirm that increases in short-term PM_{2.5} exposure are associated with an increased risk for PVCs. Owing to the large, diverse cohort of REGARDS, we were able to show that this relationship is not modified by age, race, or sex. Our findings are consistent with prior studies that have shown an increased risk for PVCs among persons with known cardiovascular disease (Bartell et al., 2013; Berger et al., 2006; Dockery et al., 2005; Rich et al., 2005). Additionally, our results show that long-term exposure to higher PM_{2.5} levels is associated with an increased risk for PVCs. To our knowledge, this finding has not been previously reported. Overall, our data suggest that short- and long-term PM_{2.5} exposures are important in the development of PVCs.

Several explanations have been proposed to link PM exposure with PVCs. PM exposure has been shown to increase the presence of ventricular arrhythmias by altering carotid body sensitivity and by inducing cardiac sodium channel dysfunction (Wang et al., 2012). Air pollution also has been associated with conduction and repolarization abnormalities which possibly increase the risk for PVCs (Van Hee et al., 2011). Furthermore, exposure to modest levels of air pollution have been shown to increase serum markers of inflammation which possibly alters myocardial substrate, leading to myocardial irritability (Adar et al., 2015). Additionally, the relationship between PM exposure and PVCs possibly depends on underlying myocardial vulnerability, such as the presence of coronary heart disease. Ischemic myocardial changes would result in underlying fibrosis that increase the risk for arrhythmia (Francis Stuart et al., 2015). This provides a plausible explanation for the differential association observed between short-term PM_{2.5} exposure and PVCs by cardiovascular disease. However, this was not observed in the long-term exposure analysis. Overall, the relationship likely is multifactorial and related to the aforementioned mechanisms which ultimately lead to PVCs.

The association between PM exposure and adverse cardiovascular events has been well-described (Auchincloss et al., 2008; Brook et al., 2004; Diez Roux et al., 2008; Krishnan et al., 2012; Miller et al., 2007; Park et al., 2010; Pope et al., 2004; Rosenlund et al., 2006). The data provided in this analysis extend previous work by showing that higher levels of PM exposure increase the risk for PVCs in a biracial population-based study of men and women. Additionally, PVCs are not benign electrocardiographic findings, as they have been associated with an increased risk of cardiovascular mortality and stroke (Agarwal et al., 2015; Engel et al., 2007). Accordingly, the findings in this analysis implicate air pollution as

a serious public health problem, as the increased risk of cardiovascular mortality associated with PVCs possibly is linked to PM exposure (Pope et al., 2015). It also is possible that air pollution is a modifiable risk factor for arrhythmia development and regulations aimed to reduce the level of ambient PM_{2.5} concentration should be considered. As we strive for more cost-effective options within our health care system, interventions aimed to reduce air pollution possibly will decrease cardiovascular mortality through reductions in the occurrence of PVCs. However, the proposed mechanism through which air pollution, PVCs, and cardiovascular mortality are linked is purely speculative and further studies are needed to support this hypothesis.

The results of the current analysis should be interpreted in the context of certain limitations. Several baseline characteristics (e.g., current smoking) were self-reported and subjected our analysis to recall bias. PVCs were detected from a single electrocardiogram recording and participants possibly would be reclassified with subsequent tracings or longer monitoring techniques (e.g., Holter monitors). It is possible that the relationship between PVCs and PM_{2.5} varies with different durations to define short-term exposure (e.g., hourly). Similar variation also is possible with long-term PM_{2.5} exposure. Additionally, other meteorologic data were not collected in our cohort and we were unable to incorporate these covariates into our multivariable models. We also adjusted for geographic region (e.g., stroke belt, stroke buckle, non-belt) and it is unclear if this classification scheme captures regional differences in PM_{2.5} exposure. Furthermore, we included several risk factors associated with PVCs in our multivariable models but cannot exclude the possibility of residual confounding similar to other epidemiologic studies.

In conclusion, we have shown that higher levels of PM_{2.5} exposure are associated with an increased risk for PVCs in a biracial population-based study of men and women. Additionally, the relationship between short-term PM_{2.5} exposure and PVCs possibly depends on the presence of cardiovascular disease.

Acknowledgments

FUNDING

This research project is supported by a cooperative agreement U01-NS041588 from the National Institute of Neurological Disorders and Stroke, National Institutes of Health, Department of Health and Human Service as well as from the NASA Applied Sciences Program. Research reported in this publication also was supported by the National Heart, Lung, And Blood Institute of the National Institutes of Health under Award Number F32-HL134290. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institute of Neurological Disorders and Stroke, National Institutes of Health, or NASA.

The authors thank the other investigators, the staff, and the participants of the REGARDS study for their valuable contributions. A full list of participating REGARDS investigators and institutions can be found at <http://www.regardsstudy.org>.

REFERENCES

- Adar SD, et al. Markers of inflammation and coagulation after long-term exposure to coarse particulate matter: a cross-sectional analysis from the multi-ethnic study of atherosclerosis. *Environ Health Perspect.* 2015; 123:541–548. [PubMed: 25616153]
- Agarwal SK, et al. Premature ventricular complexes on screening electrocardiogram and risk of ischemic stroke. *Stroke.* 2015; 46:1365–1367. [PubMed: 25873602]

- Al-Hamdan MZ, et al. Environmental Public Health Applications Using Remotely Sensed Data. *Geocarto Int.* 2014; 29:85–98. [PubMed: 24910505]
- Al-Hamdan MZ, et al. Methods for characterizing fine particulate matter using ground observations and remotely sensed data: potential use for environmental public health surveillance. *J Air Waste Manag Assoc.* 2009; 59:865–881. [PubMed: 19645271]
- Auchincloss AH, et al. Associations between recent exposure to ambient fine particulate matter and blood pressure in the Multi-ethnic Study of Atherosclerosis (MESA). *Environ Health Perspect.* 2008; 116:486–491. [PubMed: 18414631]
- Bartell SM, et al. Particulate air pollution, ambulatory heart rate variability, and cardiac arrhythmia in retirement community residents with coronary artery disease. *Environ Health Perspect.* 2013; 121:1135–1141. [PubMed: 23838152]
- Berger A, et al. Runs of ventricular and supraventricular tachycardia triggered by air pollution in patients with coronary heart disease. *J Occup Environ Med.* 2006; 48:1149–1158. [PubMed: 17099451]
- Brook RD, et al. Air pollution and cardiovascular disease: a statement for healthcare professionals from the Expert Panel on Population and Prevention Science of the American Heart Association. *Circulation.* 2004; 109:2655–2671. [PubMed: 15173049]
- Cosgrove BA, et al. Real-time and retrospective forcing in the North American Land Data Assimilation System (NLDAS) project. *J Geophys Res.* 2003; 108:8842–8854.
- Diez Roux AV, et al. Long-term exposure to ambient particulate matter and prevalence of subclinical atherosclerosis in the Multi-Ethnic Study of Atherosclerosis. *Am J Epidemiol.* 2008; 167:667–675. [PubMed: 18227099]
- Dockery DW, et al. Association of air pollution with increased incidence of ventricular tachyarrhythmias recorded by implanted cardioverter defibrillators. *Environ Health Perspect.* 2005; 113:670–674. [PubMed: 15929887]
- Engel G, et al. Prognostic significance of PVCs and resting heart rate. *Ann Noninvasive Electrocardiol.* 2007; 12:121–129. [PubMed: 17593180]
- Francis Stuart SD, et al. The crossroads of inflammation, fibrosis, and arrhythmia following myocardial infarction. *J Mol Cell Cardiol.* 2015; 91:114–122. [PubMed: 26739214]
- He F, et al. Acute effects of fine particulate air pollution on cardiac arrhythmia: the APACR study. *Environ Health Perspect.* 2011; 119:927–932. [PubMed: 21398201]
- Howard G, et al. Evaluation of social status as a contributing factor to the stroke belt region of the United States. *Stroke.* 1997; 28:936–940. [PubMed: 9158628]
- Howard VJ, et al. The reasons for geographic and racial differences in stroke study: objectives and design. *Neuroepidemiology.* 2005; 25:135–143. [PubMed: 15990444]
- Krishnan RM, et al. Vascular responses to long- and short-term exposure to fine particulate matter: MESA Air (Multi-Ethnic Study of Atherosclerosis and Air Pollution). *J Am Coll Cardiol.* 2012; 60:2158–2166. [PubMed: 23103035]
- Liao D, et al. Ambient particulate air pollution and ectopy--the environmental epidemiology of arrhythmogenesis in Women's Health Initiative Study, 1999–2004. *J Toxicol Environ Health A.* 2009; 72:30–38. [PubMed: 18979352]
- Miller KA, et al. Long-term exposure to air pollution and incidence of cardiovascular events in women. *N Engl J Med.* 2007; 356:447–458. [PubMed: 17267905]
- Park SK, et al. Particulate air pollution, metabolic syndrome, and heart rate variability: the multi-ethnic study of atherosclerosis (MESA). *Environ Health Perspect.* 2010; 118:1406–1411. [PubMed: 20529761]
- Pope CA 3rd, et al. Cardiovascular mortality and long-term exposure to particulate air pollution: epidemiological evidence of general pathophysiological pathways of disease. *Circulation.* 2004; 109:71–77. [PubMed: 14676145]
- Pope CA 3rd, et al. Relationships between fine particulate air pollution, cardiometabolic disorders, and cardiovascular mortality. *Circ Res.* 2015; 116:108–115. [PubMed: 25348167]
- Prineas, RJ., et al. The Minnesota code manual of electrocardiographic findings : standards and procedures for measurement and classification. London: Springer; 2010.

- Rich DQ, et al. Association of short-term ambient air pollution concentrations and ventricular arrhythmias. *Am J Epidemiol.* 2005; 161:1123–1132. [PubMed: 15937021]
- Rosenlund M, et al. Long-term exposure to urban air pollution and myocardial infarction. *Epidemiology.* 2006; 17:383–390. [PubMed: 16699471]
- Sokolow M, Lyon TP. The ventricular complex in left ventricular hypertrophy as obtained by unipolar precordial and limb leads. *Am Heart J.* 1949; 37:161–186. [PubMed: 18107386]
- Soliman EZ, et al. Calculating Cornell voltage from nonstandard chest electrode recording site in the Reasons for Geographic And Racial Differences in Stroke study. *J Electrocardiol.* 2010; 43:209–214. [PubMed: 20004413]
- Van Hee VC, et al. Association of long-term air pollution with ventricular conduction and repolarization abnormalities. *Epidemiology.* 2011; 22:773–780. [PubMed: 21918454]
- Wang T, et al. Particulate matter induces cardiac arrhythmias via dysregulation of carotid body sensitivity and cardiac sodium channels. *Am J Respir Cell Mol Biol.* 2012; 46:524–531. [PubMed: 22108299]

HIGHLIGHTS

- Short- and long-term PM_{2.5} exposures are associated with an increased risk for premature ventricular contractions (PVC).
- Short-term PM_{2.5} exposure increases the risk for PVCs in persons with cardiovascular disease.
- Air pollution possibly is a modifiable risk factor for ventricular arrhythmias.
- Interventions that reduce air pollution will possibly decrease cardiovascular mortality through reductions in ventricular arrhythmias.

Table 1

Baseline Characteristics (N=26,121)

Characteristic	PVCs (n=1,719)	No PVCs (n=24,402)	P-value*
Age, mean (SD), years	69 (9.3)	64 (9.2)	<0.0001
Male (%)	937 (55)	10,696 (44)	<0.0001
Black (%)	751 (44)	9,910 (41)	0.012
Region			
Stroke belt (%)	582 (34)	8,557 (35)	
Stroke buckle (%)	324 (19)	5,140 (21)	
Non-belt (%)	813 (47)	10,705 (44)	0.013
Education, high school or less (%)	750 (44)	9,171 (38)	<0.0001
Income, <\$20,000 (%)	368 (21)	4,220 (17)	<0.0001
Current smoker (%)	237 (14)	3,598 (15)	0.28
Diabetes (%)	414 (24)	4,970 (20)	0.0002
Systolic blood pressure, mean (SD), mm Hg	131 (18)	127 (16)	<0.0001
Body mass index, mean (SD), kg/m ²	29 (6.2)	29 (6.1)	0.73
Total cholesterol, mean (SD), mg/L	187 (41)	193 (40)	<0.0001
HDL cholesterol, mean (SD), mg/L	51 (16)	52 (16)	0.0079
Aspirin (%)	866 (50)	10,418 (43)	<0.0001
Antihypertensive medications (%)	1,004 (58)	12,269 (50)	<0.0001
Lipid-lowering medications (%)	621 (36)	8,012 (33)	0.0050
Left ventricular hypertrophy (%)	208 (12)	2,311 (9.5)	0.0004
Cardiovascular disease (%)	553 (32)	4,923 (20)	<0.0001
2-week PM _{2.5} , µg/m ³			
Mean (SD)	13.6 (4.1)	13.4 (4.1)	0.058
Median	12.9	12.8	
2-week Temperature, C			
Mean (SD)	17.1 (8.5)	16.6 (8.5)	0.0098
Median	17.7	18.3	
1-year PM _{2.5} , µg/m ³			
Mean (SD)	13.5 (1.9)	13.4 (1.9)	0.0083
Median	13.7	13.5	
1-year Temperature, C			
Mean (SD)	15.6 (4.1)	16.0 (4.0)	<0.0001
Median	16.4	16.6	

* Statistical significance for categorical variables tested using the chi-square method and for continuous variables the student's t-test was used.

C=Celsius; HDL=high-density lipoprotein; PM=particulate matter; PVC=premature ventricular contraction; SD=standard deviation.

Table 2Association of Short-Term PM_{2.5} Exposure with PVCs

	Model 1 [‡] OR (95%CI)	P-value	Model 2 [‡] OR (95%CI)	P-value	P-interaction ^δ
No PVC	Ref	-	Ref	-	
PVC	1.09 (1.03, 1.14)	0.0015	1.08 (1.03, 1.14)	0.0019	
Age					
<65	1.08 (0.99, 1.18)	0.058	1.08 (0.99, 1.18)	0.069	0.98
65	1.08 (1.02, 1.15)	0.015	1.08 (1.01, 1.15)	0.019	
Sex					
Female	1.09 (1.01, 1.17)	0.025	1.09 (1.01, 1.17)	0.026	0.79
Male	1.08 (1.01, 1.16)	0.023	1.08 (1.01, 1.16)	0.026	
Race					
Black	1.10 (1.01, 1.18)	0.022	1.10 (1.01, 1.19)	0.021	0.56
White	1.08 (1.01, 1.15)	0.027	1.08 (1.01, 1.15)	0.029	
Cardiovascular Disease					
No	1.05 (0.99, 1.12)	0.11	1.05 (0.99, 1.12)	0.12	0.027
Yes	1.16 (1.06, 1.27)	0.0011	1.16 (1.06, 1.27)	0.0010	

^{*} OR presented per 1-SD increase (4.07 µg/m³) in PM_{2.5} exposure.[‡] Model 1 adjusted for age, sex, race, education, income, geographic region, and average temperature.[‡] Model 2 adjusted for covariates in Model 1 with the addition of systolic blood pressure, high-density lipoprotein cholesterol, total cholesterol, body mass index, smoking, diabetes, antihypertensive medications, lipid-lowering therapies, left ventricular hypertrophy, and prior history of cardiovascular disease.^δ Interactions tested using Model 2.

CI=confidence interval; OR=odds ratio; PM=particulate matter; PVC=premature ventricular contraction.

Table 3Association of Long-Term PM_{2.5} Exposure with PVCs^{*}

	Model 1 [†] OR (95%CI)	P-value	Model 2 [‡] OR (95%CI)	P-value	P-interaction ^δ
No PVC	Ref	-	Ref	-	
PVC	1.07 (1.01, 1.12)	0.014	1.06 (1.01, 1.12)	0.025	
Age					
<65	1.11 (1.02, 1.22)	0.020	1.11 (1.01, 1.21)	0.031	0.19
65	1.04 (0.98, 1.11)	0.21	1.04 (0.97, 1.10)	0.30	
Sex					
Female	1.07 (0.99, 1.15)	0.11	1.06 (0.98, 1.15)	0.15	0.76
Male	1.07 (0.99, 1.15)	0.054	1.07 (0.99, 1.14)	0.078	
Race					
Black	1.05 (0.97, 1.14)	0.21	1.05 (0.97, 1.14)	0.24	0.80
White	1.08 (1.00, 1.15)	0.041	1.07 (0.99, 1.15)	0.057	
Cardiovascular Disease					
No	1.05 (0.99, 1.12)	0.14	1.05 (0.98, 1.12)	0.16	0.39
Yes	1.11 (1.01, 1.21)	0.035	1.10 (1.00, 1.21)	0.043	

^{*} OR presented per 1-SD increase (1.93 µg/m³) in PM_{2.5} exposure.[†] Model 1 adjusted for age, sex, race, education, income, geographic region, and average temperature.[‡] Model 2 adjusted for covariates in Model 1 with the addition of systolic blood pressure, high-density lipoprotein cholesterol, total cholesterol, body mass index, smoking, diabetes, antihypertensive medications, lipid-lowering therapies, left ventricular hypertrophy, and prior history of cardiovascular disease.^δ Interactions tested using Model 2.

CI=confidence interval; OR=odds ratio; PM=particulate matter; PVC=premature ventricular contraction.