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Exposure to ambient air pollution and blood lipids in adults: The 33 Communities Chinese Health Study

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ABSTRACT

Background: Little information exists on the lipidemic effects of air pollution, particularly in developing countries. We aimed to investigate the associations of long-term exposure to ambient air pollutants with lipid levels and dyslipidemias in China.

Methods: In 2009, a total of 15,477 participants aged 18–74 years were recruited from the 33 Communities Chinese Health Study conducted in three Northeastern China cities. Total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C) were measured in participants' blood specimens. Three year (2006–08) average air pollution concentrations were assessed using data from 33 communities (particles with diameters ≤1.0 μm (PM_1) and ≤2.5 μm ($PM_{2.5}$) were predicted using a spatial statistical model) or 11 air monitoring stations (particles with diameters ≤10 μm (PM_{10}), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and ozone (O_3)). Associations were evaluated by two-level logistic and generalized linear regression models.

Results: We detected many significant associations between exposure to air pollutants (especially for PM_1 and $PM_{2.5}$) and blood lipid levels. Most of the associations suggested deleterious effects on blood lipid markers (e.g.,

Abbreviations: BMI, body mass index; CI, confidence interval; CVD, cardiovascular diseases; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; NO_2, nitrogen dioxide; OR, odds ratio; O_3, ozone; PM_1, particles with diameters ≤1.0 μm; $PM_{2.5}$, particles with diameters ≤2.5 μm; PM_{10}, particles with diameters ≤10 μm; $PM_{2.5-10}$, particles with diameters ranging from 2.5 to 10 μm; SEPA, the State Environmental Protection Administration of China; SO_2, sulfur dioxide; TC, total cholesterol; TG, triglycerides; 33CCHS, the 33 Chinese Community Health Study

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a 10 μg/m^3 increase in PM_1 was associated with 1.6% (95% confidence interval (CI): 1.1, 2.0), 2.9% (95% CI: −3.3, 9.3), and 3.2% (95% CI: 2.6, 3.9) higher levels of TC, TG, and LDL-C, respectively, but 1.4% (95% CI: −1.8, −0.9) lower HDL-C levels), although beneficial associations were found for O_3. In analysis with dyslipidemias, all the observed associations suggested deleterious lipidemic effects of air pollutants, and no significant beneficial association was observed for O_3. Stratified analyses showed that the associations were stronger in overweight or obese participants; sex and age modified the associations, but the pattern of effects was mixed.

Conclusions: Long-term ambient air pollution was associated with both altered lipid profiles and dyslipidemias, especially among overweight or obese participants.

1. Introduction

Cardiovascular diseases (CVD) are responsible for approximately 31% of deaths worldwide (Word Health Organization, 2017) and the results of numerous epidemiological studies have supported a causal relation for long-term air pollution exposure with CVD (Brook et al., 2010; Bourdrel et al., 2017). Inhaled air pollutants trigger inflammation, oxidative stress, autonomic imbalance, and epigenetic changes (Brook et al., 2010; Bourdrel et al., 2017). These reactions have been linked to several CVD risk factors, including atherosclerosis, hypertension, diabetes mellitus, and dyslipidemia (Brook et al., 2010; Thiering and Heinrich, 2015; Rajagopalan and Brook, 2012; Yang et al., 2018). For example, higher levels of particulate matter (PM) have been linked to increased systemic inflammation (Brook et al., 2010), which can lead to adverse lipid metabolism and lipid oxidation (Chen et al., 2013). The relationships of air pollution with hypertension and diabetes mellitus have been demonstrated by many epidemiological and experimental studies (Brook et al., 2010; Rajagopalan and Brook, 2012; Thiering and Heinrich, 2015), including our own (Dong et al., 2013; Yang et al., 2017; Yang et al., 2018).

Dyslipidemia, characterized by hypercholesterolemia, hypertriglyceridemia, hypoalphalipoproteinemia, and/or hyperbetalipoproteinemia, is the foremost cause of atherosclerosis (Stensland-Bugge et al., 2000) and is inextricably related to the development of CVD (Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults, 2001). The global prevalence of dyslipidemias is high and increasing (Cahalin et al., 2014). For example, a 2013 report from the American Heart Association suggested that the prevalences of hypercholesterolemia, hypoalphalipoproteinemia, and hyperbetalipoproteinemia in American adults were 43.4%, 21.8%, and 31.1%, respectively (Go et al., 2013). Several previous epidemiological studies explored relationships between ambient air pollutant exposure and dyslipidemia and blood lipid levels, yet the results were inconsistent (Bell et al., 2017; Bind et al., 2016; Cai et al., 2017; Chuang et al., 2011; Jiang et al., 2016; Poursafa et al., 2014; Shanley et al., 2016; Sørensen et al., 2015; Wallwork et al., 2017; Yeatts et al., 2007; Yitshak Sade et al., 2016) (see Table S1). Additionally, most studies investigated effects among specific populations, including asthmatics (Yeatts et al., 2007), patients with chronic diseases (Yitshak Sade et al., 2016), the elderly (Bind et al., 2016; Chuang et al., 2011; Sørensen et al., 2015; Wallwork et al., 2017), and adolescents (Poursafa et al., 2014). However, the lipidemic effects of air pollution exposure were rarely evaluated in general populations. Moreover, previous studies were mostly conducted in high-income nations or regions (Bell et al., 2017; Bind et al., 2016; Chuang et al., 2011; Shanley et al., 2016; Sørensen et al., 2015; Wallwork et al., 2017; Yeatts et al., 2007; Yitshak Sade et al., 2016). There are few data available to characterize the risks of air pollution exposure on lipid levels and dyslipidemia in low-income countries.

In recent decades, China has experienced a gradual increase in the prevalence of dyslipidemia, although it remains lower than that in many developed countries (Pan et al., 2016). For instance, the 2002 China National Nutrition and Health Survey reported that the prevalences of hypercholesterolemia, hyperbetalipoproteinemia, hypoalphalipoproteinemia, and hypertriglyceridemia were 2.9%, 2.5%, 7.4%, and 11.9%, respectively (Zhao, 2008), while the corresponding 2013–2014 China Chronic Disease and Risk Factor Surveillance prevalences were 6.9%, 8.1%, 20.4%, and 13.8% (Zhang et al., 2018). Simultaneously, air pollution has emerged as a severe environmental problem in China (Guan et al., 2016; Rohde and Muller, 2015). Given temporal increases in both ambient air pollution and the prevalence of dyslipidemia, and the scarcity of data, it is of significant public health importance to explore the relationship between the two. To begin to address the data gap, this study examined associations between long-term residential ambient air pollution and blood lipid levels in a large community-based sample of urban adults participating in the 33 Chinese Community Health Study (33CCHS).

2. Methods

2.1. Study population

The population of the 33CCHS was previously described in detail (Dong et al., 2013; Yang et al., 2017). Briefly, in 2009, we used a random-number generator coupled to a four-staged, stratified, cluster sampling strategy to recruit study participants. First, to maximize the inter-city gradients of air pollutants, we randomly selected three cities - Shenyang, Anshan, and Jinzhou - from 14 total cities in Liaoning province. There are five districts in Shenyang city and three each in the cities of Anshan and Jinzhou. Second, we randomly selected three communities from each of the districts, generating a total of 33 study communities. Each study community was approximately 0.25–0.64 km^2 in area. Third, we randomly selected 700–1000 households from each study community. Fourth, from each study household, we randomly selected one adult aged 18 to 74 years for study enrollment. To be included, individuals had to live at the study address for at least five years, have no severe pre-existing diseases (e.g., cancers), and not be pregnant. Based on the sampling frame, 28,830 participants were invited, of whom 24,845 individuals completed the survey, yielding an overall response rate of 86.2%. A total of 9368 individuals were excluded from the present analysis due to refusal to provide a blood sample, leaving a final sample of 15,477 participants (62.3% of the 33CCHS participants). All participants completed informed consent prior to study enrollment, and Sun Yat-Sen University's Human Studies Committee reviewed and approved all study procedures and protocols.

2.2. Health outcomes

After an overnight fast, peripheral venous blood samples were collected from study participants. Total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C) levels were determined using a Hitachi Autoanalyzer (Type 7170A; Hitachi Ltd.; Tokyo, Japan). Hypercholesterolemia was defined as TC ≥ 240 mg/dL; hypertriglyceridemia was defined as TG ≥ 200 mg/dL; hypoalphalipoproteinemia was defined as HDL-C ≤ 40 mg/dL; and hyperbetalipoproteinemia was defined as LDL-C ≥ 160 mg/dL (Joint Committee for Developing Chinese Guidelines on Prevention and Treatment of