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Assessing the associations of daily respiratory symptoms and lung function in schoolchildren using an Air Quality Index for ozone: Results from the RESPOZE panel study in Athens, Greece

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HIGHLIGHTS

- A local ozone Air Quality Index (AQI) is associated with respiratory health in children.
- Locally derived AQI is a better health predictor compared to an AQI based on a wider area.
- Use of AQI resulted in better model fit compared to measurements.
- The AQI may be useful in improving communication with the public.

GRAPHICAL ABSTRACT

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ABSTRACT

Background: Air Quality indicators or indices (AQIs) are mainly used for communicating the air pollution levels and risk to the general population. However, very few epidemiological studies have used AQIs for characterizing exposure.
Objective: In the framework of the RESPOZE panel study we evaluated the association of daily ozone AQI levels with the daily occurrence of respiratory symptoms and Peak Expiratory Flow (PEF) and compared the effects with those estimated using measurements from fixed outdoor monitoring sites, in the city of Athens, Greece.
Materials and methods: A panel of 97 children, aged 10–11 years, was followed intensively for 35 days (5 weeks) during the academic year 2013–14. PEF and symptoms were recorded daily by each child. Two ozone AQIs classifying the air quality into 7 categories of increasing severity, were calculated; one characterizing the whole Athens area and one the local area around the child's residence and school. Measurements from fixed sites were also used. Mixed effects models for repeated measurements were applied, adjusting for several confounders.
Results: Increasing ozone levels were associated with increased incidence of symptoms, but the strongest and most statistically significant associations were found with the local air quality characterization with the AQI. Specifically, an increase in AQI-local by one category was associated with 34% (95% CI: 9%, 64%) increased odds of stuffy nose. When the AQI categories were "Bad" and "Severe", an increase in the incidence of cough was observed (OR 3.05 (95% CI: 1.29, 7.22) and 6.42 (95% CI: 1.47, 28.03) respectively). We did not observe a statistically significant association between AQI and PEF.

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Conclusion: Our results show that the use of an AQI based on local conditions may be advantageous over the use of only measurements when investigating the effects of air pollution on health outcomes for improving communication of risk to the public.

1. Introduction

The adverse health effects of short and long-term exposure to several air pollutants have been studied and documented in the past although questions remain and further research is in progress (Gryparis et al., 2004; Von Klot et al., 2005; Kaur et al., 2007; Raaschou-Nielsen et al., 2013; WHO, 2013; Beelen et al., 2014). One open issue is the way individual exposure should be assessed taking into account space and time variability in pollutants concentrations and the highly variable time-activity patterns between individuals (Borgini et al., 2015). More evidence and attention has accumulated on the health effects of particulate matter (PM) (WHO, 2013) but recently ozone exposure has also attracted renewed attention (Schwartz, 2016), although the acute effects of ozone exposures were known from older studies (Mudway and Kelly, 2000). In epidemiological studies exposure is often estimated through the use of measurements from the fixed monitoring sites (Kaur et al., 2007; Sarnat et al., 2010), providing the same estimates for the population of a whole area or differentiating spatially using the nearest monitor to a subject's residence, or, other studies apply modeling approaches which provide spatial or spatio-temporal differentiation (Jerrett et al., 2005; Maynard et al., 2007).

Given the consensus on health effects of exposure to pollutants, many policy institutions attempt to produce guidelines for informing and protecting the public from air pollution exposure based on epidemiological evidence. In order to better communicate environmental quality on a daily basis, Air Quality Indicators or indices (AQI) have been developed (Garcia and Colosio, 2002; Murena, 2004; Stieb et al., 2008; AIRKOREA, 2017), based on the daily measurements of the local monitoring networks, in order to characterize the air quality by using indexing scales and a few categories labeled appropriately (e.g. good, moderate, unhealthy), suitable for public reporting. Various AQI have been developed, either assessing the air quality for one (Franceschini et al., 2005) or several pollutants combined (Kyrkilis et al., 2007). To form an AQI, the WHO air quality guidelines or legal limit values may be used and are sometimes considered together with the distributions of local concentrations of pollutants, resulting in the same characterization (e.g. "good") of different concentration levels depending on the "usual" measurements in each area (DEFRA, 2013; EEA, 2013; Kassomenos et al., 1998; Kassomenos et al., 1999; Kyrkilis et al., 2007; Plaia and Ruggieri, 2011; EPA, 2014). For example, the U.S. E.P.A. has developed an AQI that is directly based on health effects to communicate information about localized air pollution, using a scale of six levels of health-relevant concern with a different color characterizing each level. This AQI is based on measured concentrations for each regulated pollutant that are converted into a separate pollutant-specific AQI that are subsequently combined with formulas developed by EPA (www.airnow.gov). Because of the variety of methods for the conversion of concentrations into an AQI, the air pollution concentrations in each AQI category, their labeling and description, often differ from one country or region to another (Wong, 2012). AQI categories are correlated directly with measurements from the nearest outdoor fixed sites, but have less quantitative information. They may vary greatly by location when they characterize different air pollutant concentrations as e.g. "poor" based on the "usual" local conditions (Kassomenos et al., 1998; Kassomenos et al., 1999).

AQI can also be beneficial for assessing population exposure to air pollution and predicting the magnitude of the general health risks. The advantage is that the indexed scales can be normalized, taking the "usual" local air quality conditions into account, as opposed to concentration scales, which are not (Zujic et al., 2009). Very few studies to date have investigated the association of the AQIs with health outcomes. However, it is useful to assess whether these are appropriate exposure indicators or indices reflecting the associations with health in order to evaluate the information provided to the general public and enable informative and straightforward policy statements (Plaia and Ruggieri, 2011).

Within the framework of the "Respiratory Effects of Ozone Exposure in Children-RESPOZE" panel study in Athens, Greece during 2013–14, that assessed respiratory health in a representative population sample of 10–11 year old students, ozone AQIs have been developed for the whole of Athens Metropolitan area, as well as for locations around each fixed monitoring site. Based on these, each child's daily ozone exposure at the school and residence area was characterized for the follow up period. In this paper we evaluate the association of the daily AQI levels with the daily occurrence of respiratory symptoms and self-measured Peak Expiratory Flow (PEF) and compare their effects with those estimated using measurements from fixed outdoor monitoring sites.

2. Subjects and methods

2.1. Study design and sampling

In order to recruit the population representative panel of students, ensuring ozone exposure contrasts, a two-stage design was implemented: in the first stage elementary schools placed within 2 km from a fixed monitoring site in the city of Athens (population about 3 m, www.statistics.gr) were sampled. Vicinity to the monitoring sites provided the possibility for a good characterization of air pollution at the schools for all regulated pollutants, such as Ozone (O_3), PM with an aerodynamic diameter <10 μm (PM_{10}) and nitrogen dioxide (NO_2). Twenty one schools were chosen that were classified in "low" and "high" O_3 areas based on historical measurements. Only state schools were considered as students have to live near the school in order to attend. At the second stage of the sampling design we visited fifth grade classes (10 to 11-year-old students), informed the children about the project, obtained informed consent forms from the parents of children willing to participate and finalized our sample consisting of 97 children, with 1 to 19 students per school, ensuring that about 60% of children would be sampled from the high ozone area schools. Each child was followed for five intensive field work weeks (35 non-consecutive days) during the academic year 2013–14: two in the fall (October–November), one in the winter (February) and two in the spring and early summer (April–May). Before the start of the field work, trained interviewers visited the families of the children and administered an extensive questionnaire with information on demographic, lifestyle and residential characteristics, as well as on the medical history of the child. At this visit the students were provided with a peak flow meter (mini-Wright; Clement Clarke International, Edinburgh, UK) and given extensive instructions on its use. A team of three professionals, including one pediatrician or pulmonologist and two nurses, visited students at their school environments twice for each field work week on the same weekday. At the first visit a time activity diary (TAD) was distributed to each student to be self-completed. In the TAD information was recorded for each day of the study period on: the student's location (defined as: at home, out of home outdoors, out of home indoors and in transport) at 15 min intervals; symptoms, namely cough, wheezing, dyspnea, fever and stuffy nose; absenteeism from school; medication