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Multifactorial airborne exposures and respiratory hospital admissions — The example of Santiago de Chile

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HIGHLIGHTS

- We assessed effects of multiple airborne exposures on respiratory hospital admissions of the population of Santiago de Chile.
- We found significant adverse effects for CO, NO_2, PM10 and PM2.5, but not O_3.
- Effect strength and lag time depend on the type of pollutant.
- Different airborne pollutants account for varying adverse effects.

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ABSTRACT

Our results provide evidence for respiratory effects of combined exposure to airborne pollutants in Santiago de Chile. Different pollutants account for varying adverse effects. Ozone was not found to be significantly associated with respiratory morbidity.

Background: High concentrations of various air pollutants have been associated with hospitalization due to development and exacerbation of respiratory diseases. The findings of different studies vary in effect strength and are sometimes inconsistent.

Objectives: We aimed to assess associations between airborne exposures by particulate matter as well as gaseous air pollutants and hospital admissions due to respiratory disease groups under the special orographic and meteorological conditions of Santiago de Chile.

Methods: The study was performed in the metropolitan area of Santiago de Chile during 2004–2007. We applied a time-stratified case-crossover analysis taking temporal variation, meteorological conditions and autocorrelation into account. We computed associations between daily ambient concentrations of carbon monoxide (CO), nitrogen dioxide (NO_2), particulate matter (PM10 and PM2.5 — particulate matter with aerodynamic diameters less than 10 or 2.5 μm, respectively) or ozone (O_3) and hospital admissions for respiratory illnesses.

Results: We found for CO, NO_2, PM10 and PM2.5 adverse relationships to respiratory admissions while effect strength and lag depended on the pollutant and on the disease group. By trend, in 1-pollutant models most adverse pollutants were CO and PM10 followed by PM2.5, while in 2-pollutant models effects of NO_2 persisted in most cases whereas other effects weakened and significant effects remain for PM2.5, only. In addition the strongest effects seemed to be immediate or with a delay of up to one day, but effects were found until day 7, too. Adverse effects of ozone could not be detected.

Conclusions: Taking case numbers and effect strength of all cardiovascular diseases into account, mitigation measures should address all pollutants especially CO, NO_2, and PM10.

1. Introduction and aim of the study

A preceding study investigated the air pollution related cardiovascular hospital admissions in the city of Santiago de Chile (Franck et al., 2014). This present study is based on the same time period and exposure data but aimed at respiratory morbidity.

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1.1. Results on respiratory health effects of particulate matter, CO, NO_2, and O_3 vary between studies

A number of studies have shown the detrimental effects of single common airborne pollutants on respiratory hospital admissions, doctor's house calls and emergency calls (Atkinson et al., 2012; Brunekreef, 2007; Hoek et al., 2013; Leitte et al., 2011, 2012). Increased health risks were also found for the conditions of Santiago de Chile (Bell et al., 2006; Cakmak et al., 2011, 2009b; Franck et al., 2014; Segual et al., 2012; Vera and Cifuentes, 2008; Vera et al., 2007).

Effect strengths for particulate matter vary between studies. Typically an increase of concentrations of ambient particulate matter (PM10, PM2.5) by 10 μg/m^3 was found to be associated with a 3% to 6% increase of respiratory admissions and emergency calls by 3–12% per day (Chardon et al., 2007; Dominici et al., 2006; Fung et al., 2006; Jayaraman and Nidhi, 2008; Lippmann et al., 2000; Oftedal et al., 2003; Stieb et al., 2009; Tramuto et al., 2011). But, a small number of authors found considerable lower effect strengths (Jayaraman and Nidhi, 2008; Son et al., 2013). The different studies also found different time lags for respiratory health effects. Often, but not always a significant risk increase was found already for the day of exposure. The effects persisted some days up to around one week. The present study therefore wants to contribute to this discussion investigating strengths and lags of adverse effects of PM exposure on respiratory health in the city of Santiago de Chile.

Nitrogen dioxide is another urban pollutant known to be associated with detrimental respiratory effects. For doctor's house calls no significant risk increase could be shown (Chardon et al., 2007). But, the risk for hospital admissions was found to be increased by 4% up to 11% per 10 μg NO_2/m^3 (Ackermann-Liebrich, 2011; Brunekreef, 2007; Jayaraman and Nidhi, 2008; Lee et al., 2007; Oftedal et al., 2003; Peel et al., 2005; Simpson et al., 2005; Spix et al., 1998; Stieb et al., 2009; Tramuto et al., 2011; Yang and Chen, 2007). Because NO_2 is a typical urban pollutant in Santiago de Chile related to traffic as an important source of various pollutants this study aimed also on effect strengths and lags of NO_2 associated hospital admissions.

Especially effects of O_3 were not consistent between studies. Some studies found significant numbers of respiratory hospital admissions (Chen et al., 2005; Jayaraman and Nidhi, 2008; Lee et al., 2007; Simpson et al., 2005; Spix et al., 1998; Yang and Chen, 2007) whereas other studies found no effect or a statistically protecting effect on respiratory morbidity (Fung et al., 2007; Oftedal et al., 2003). Such a statistically protecting effect was also shown for cardiovascular hospital admissions in Santiago de Chile (Franck et al., 2014).

The number of recent studies which addressed effects of CO on hospital admission is significantly lower than for the other pollutants. Additionally, the findings of former studies were not congruent. Increased exposure to CO was found to be associated with respiratory morbidity with risk increases of up to 12% per 1 mg/m^3 CO and similar lags as for PM exposure. But, risk increases and lags vary from study to study (Chen et al., 2005; Peel et al., 2005; Stieb et al., 2009; Tramuto et al., 2011). In contrast to other studies, Tramuto et al. found the effects of CO during the warm seasons, only (Tramuto et al., 2011). Therefore, the present study intended to contribute to the findings on respiratory health effects of CO.

Ozone is a pollutant linked to the intensity of sun radiation. Hence, it plays a dominant role during summer and in southern countries. O_3 exposure is accused to produce detrimental respiratory effects. But, especially effects of this pollutant were not consistent between studies. Some studies found significant numbers of respiratory hospital admissions (Chen et al., 2005; Jayaraman and Nidhi, 2008; Lee et al., 2007; Simpson et al., 2005; Spix et al., 1998; Yang and Chen, 2007) whereas other studies found no effect or a statistically protecting effect on respiratory morbidity (Fung et al., 2007; Oftedal et al., 2003). Such a statistically protecting effect was also shown for cardiovascular hospital admissions in Santiago de Chile (Franck et al., 2014). Hence, the present study wanted to verify or falsify the protecting effects of ozone on respiratory diseases.

Adverse respiratory effects of airborne pollutants may generally be caused by a mixture of pollutants and not always by a dominating pollutant or a simple superposition of the effects of single pollutants (Mauderly and Samet, 2009). The present study therefore also focused on the stability of the respiratory effects of the airborne pollutants within 2-pollutant models.

1.2. The distinctive feature of airborne outdoor exposure in Santiago de Chile

Santiago de Chile is surrounded by Andean Mountains in the east and the Cordillera of the Coast. The specific atmospheric and geographic conditions cause high contamination levels due to relatively high anthropogenic and natural emissions. Depending on season, the main contamination is due to primary emissions: particulate matter, sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and carbon monoxide (CO) (Cakmak et al., 2009b; Moreno et al., 2010; Kavouras et al., 2001). High emission levels, high solar radiation in the summer and the specific orographic conditions resulted in high levels of combined exposure of the 6 million inhabitants of Chile's capital. A more detailed description of air pollution situation in Santiago de Chile is given in Cakmak et al. (2009b), Elshorbany et al. (2009), Franck et al. (2014) and Suppan et al. (2012).

Different types of natural and anthropogenic sources emit different airborne pollutants. Identification of most adverse pollutants and mixtures of pollutions may help to develop the optimal mitigation strategies for the protection of the health of Santiago's inhabitants. Thus, this study aimed on identification of harmful pollutants for development or exacerbation of respiratory diseases. Additionally, the study focused on the persistency of the exposure by one pollutant taking a second one into account. The study also intended to contribute to the findings about air pollution associated respiratory morbidity which are partially inconsistent (see paragraph 1.2). In addition, this article compares the findings regarding respiratory hospital admissions with the findings on cardiovascular hospital admissions (Franck et al., 2014).

2. Material and methods

2.1. Study area and period

Around 88.7% of Chile's population lives in cities. In the city of Santiago (área urbana) are living around 5.39 Mio inhabitants (census 2002) which is more than one third of the total population of the country. The city lies in the center of the Santiago Basin, a large bowl-shaped valley between the Andes and the Cordillera de la Costa mountain ranges; the distance from the Pacific Ocean is 100 km (Gramsch et al., 2006). The geographic location in the Santiago Basin strongly limits ventilation and dispersion of air pollutants. During summer, central Chile is generally influenced by subtropical anticyclone in the south-eastern pacific in Santiago (Schmitz, 2005). These conditions with high temperatures and clear sky, favor the formation of ozone through the photochemical oxidation of carbon monoxide and volatile organic compounds (VOC) in the presence of high concentrations of nitrogen oxides. Daily variation of exposure concentrations is high which results in significant numbers of days on which the Chilean National Ambient Air Quality Standard (NAAQS) mean of 80 ppb maximum hourly and the NAAQS average of 61 ppb maximum over 8 h were exceeded (Bell et al., 2008; Segual et al., 2012). This limit was exceeded also during the study period from January 1, 2004 until December 31, 2007 (Franck et al., 2014).

2.2. Health data

Effects on respiratory morbidity of air pollutants were determined based on daily numbers of respiratory hospital admissions. The