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Residential air pollution does not modify the positive association between physical activity and lung function in current smokers in the ECRHS study

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Abbreviations: ALEC, Ageing Lungs in European Cohorts; BMI, body mass index; COPD, chronic obstructive pulmonary disease; ECRHS, European Community Respiratory Health Survey; ESCAPE, European Study of Cohorts for Air Pollution Effects; FEV_1, forced expiratory volume in 1 s; FVC, forced vital capacity; LUR, land use regression; NO_2, nitrogen dioxide; $PM_{2.5}$, particulate matter with aerodynamic diameters smaller than 2.5 μm; PM_{10}, particulate matter with aerodynamic diameters smaller than 10 μm; SD, standard deviation

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ABSTRACT

Background: Very few studies have examined whether a long-term beneficial effect of physical activity on lung function can be influenced by living in polluted urban areas.

Objective: We assessed whether annual average residential concentrations of nitrogen dioxide (NO_2) and particulate matter with aerodynamic diameters < 2.5 μm ($PM_{2.5}$) and < 10 μm (PM_{10}) modify the effect of physical activity on lung function among never- (N = 2801) and current (N = 1719) smokers in the multi-center European Community Respiratory Health Survey.

Methods: Associations between repeated assessments (at 27–57 and 39–67 years) of being physically active (physical activity: ≥2 times and ≥1 h per week) and forced expiratory volume in 1 s (FEV_1) and forced vital capacity (FVC) were evaluated using adjusted mixed linear regression models. Models were conducted separately for never- and current smokers and stratified by residential long-term NO_2, $PM_{2.5}$ mass and PM_{10} mass concentrations (≤75th percentile (low/medium) versus > 75th percentile (high)).

Results: Among current smokers, physical activity and lung function were positively associated regardless of air pollution levels. Among never-smokers, physical activity was associated with lung function in areas with low/medium NO_2, $PM_{2.5}$ mass and PM_{10} mass concentrations (e.g. mean difference in FVC between active and non-active subjects was 43.0 mL (13.6, 72.5), 49.5 mL (20.1, 78.8) and 49.7 mL (18.6, 80.7), respectively), but these associations were attenuated in high air pollution areas. Only the interaction term of physical activity and PM_{10} mass for FEV_1 among never-smokers was significant (p-value = 0.03).

Conclusions: Physical activity has beneficial effects on adult lung function in current smokers, irrespective of residential air pollution levels in Western Europe. Trends among never-smokers living in high air pollution areas are less clear.

1. Introduction

Regular physical activity is known to reduce the risk of numerous non-communicable diseases, such as coronary heart disease, type 2 diabetes and several types of cancer (Lee et al., 2012). Evidence for a beneficial role in maintaining respiratory health in both healthy and sick populations is also building (Brumpton et al., 2017; Cheng et al., 2003; Jakes et al., 2002; Pelkonen et al., 2003; Watz et al., 2014), with some studies reporting stronger effects among current smokers (Fuertes et al., 2018; Garcia-Aymerich et al., 2007). This latter observation may be partly attributable to the anti-inflammatory effects of regular physical activity on the inflammatory burden of smokers who are at high risk of lower lung function (Gan et al., 2005; Kasapis and Thompson, 2005).

In addition to smoking, exposure to air pollution is also pro-inflammatory. It is thus conceivable that an individual's exposure to air pollution may influence how physical activity affects respiratory health. Short-term semi-controlled studies and panel studies have yielded equivocal evidence as to whether an interaction exists between air pollution and physical activity with respect to lung function (Giles et al., 2012; Jarjour et al., 2013; Kubesch et al., 2015; Laeremans et al., 2018a; Matt et al., 2016; Strak et al., 2012; Weichenthal et al., 2011; Sinharay et al., 2017) and very few studies have examined long-term effects. One long-term study in California, USA, found that children participating in sports were more likely to develop asthma (after five years of follow-up) than those not participating in sports, but only if they lived in areas with high ozone levels (McConnell et al., 2002). Another long-term study of elderly urban residents found that home outdoor nitrogen dioxide (NO_2) concentrations did not modify the beneficial association of increased participation in sports, cycling and gardening with total, cardiovascular and diabetes mortality, although effect estimates between cycling and gardening with respiratory mortality were attenuated in high NO_2 settings (Andersen et al., 2015). Finally, a recent study reported that lung function improved with physical activity at low, but not high, black carbon levels among a sample of 115 healthy non- or ex-smoking adults (Laeremans et al., 2018b). Similar long-term studies related to other inflammatory-associated conditions, such as cardiovascular risk factors (Endes et al., 2017; Sinharay et al., 2017), are also beginning to emerge.

Understanding the interplay between air pollution, physical activity and lung function is important to inform policy efforts aimed at increasing physical activity in urban areas. Although studies are beginning to quantify the levels at which air pollution may negate the health benefits of physical activity (Tainio et al., 2016), there is currently limited evidence on which to base guidelines that either encourage physical activity in all settings or promote behavioral changes when air quality is low (as currently suggested by some agencies (Centers for Disease Control and Prevention, 2015)). Given the general paucity of long-term studies and the fact that the few that do exist on respiratory health have been conducted in specific population subgroups (children (for asthma) and the elderly (for respiratory mortality)) or are based on small sample sizes, additional population-based studies are warranted.

In a previous analysis of the prospective multi-center European Community Respiratory Health Survey (ECRHS), we reported that increased physical activity was associated with higher average forced expiratory volume in 1 s (FEV_1) and forced vital capacity (FVC) among current smokers (Fuertes et al., 2018). It is of interest to see whether concomitant exposure to high residential air pollution concentrations may affect this relationship. Under the framework of the Ageing Lungs in European Cohorts (ALEC) consortium (www.alecstudy.org), we investigated whether the positive association between physical activity and FEV_1 and FVC is modified by home outdoor concentrations of NO_2, particulate matter with aerodynamic diameters smaller than 2.5 μm ($PM_{2.5}$) and particulate matter with aerodynamic diameters smaller than 10 μm (PM_{10}).

2. Material and methods

2.1. Participants

Over 18,000 participants were originally recruited (ECRHS I) from 30 centers in 14 countries in 1991–1993 using population-based registers (representative population-based arm), with an additional sampling of asthmatics (symptomatic arm) (Janson et al., 2001). Two follow-ups have since taken place: ECRHS II in 1999–2003 (27–57 years) and ECRHS III in 2010–2014 (39–67 years). At the original recruitment and at both follow-ups, extensive lifestyle and health information was collected using questionnaires. The current analysis is restricted to data from both study arms obtained during the first (ECRHS II) and second (ECRHS III) follow-ups, during which both physical activity and spirometry data were collected (Burney et al., 1994; The European Community Respiratory Health Survey II Steering Committee, 2002).