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Physical activity, black carbon exposure and airway inflammation in an urban adolescent cohort

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ABSTRACT

Objective: Regular physical activity can improve cardiopulmonary health; however, increased respiratory rates and tidal volumes during activity may increase the effective internal dose of air pollution exposure. Our objective was to investigate the impact of black carbon (BC) measured by personal sampler on the relationship between physical activity and fractional exhaled nitric oxide (FeNO), a marker of airway inflammation. We hypothesized that higher personal BC would attenuate the protective effect of physical activity on airway inflammation.

Methods: We performed a cross-sectional study nested in a birth cohort of African American and Dominican children living in the Bronx and Northern Manhattan, New York City. Children were recruited based on age (target 9–14 year olds) and presence (n=70) or absence (n=59) of current asthma. Children wore wrist mounted accelerometers for 6 days and were classified as 'active' if they had $\geq$60 min of moderate-to-vigorous activity (MVA) each day and 'non-active' if they had $<$60 min of MVA on any given day, based on CDC guidelines. Personal BC measured using a MicroAeth, was assessed during two 24-h periods, at the beginning and end of physical activity assessment. High BC was defined as the upper tertile of BC measured with personal sampler. FeNO measurements were sampled at the beginning and end of the of physical activity assessment.

Results: In multivariable linear regression models, 'active' children had 25% higher personal BC concentrations (p=0.02) and 20% lower FeNO (p=0.04) compared to 'non-active' children. Among children with high personal BC (n=33), there was no relationship between activity and FeNO (p=1.00). The significant protective relationship between activity and airway inflammation was largely driven by children with lower personal BC (n=96, p=0.04).

Conclusions: Children that live in an urban environment and are physically active on a daily basis have higher personal exposure to BC. High BC offsets the protective relationship between physical activity and airway inflammation.

1. Introduction

Physical activity provides numerous health benefits, including improved metabolic and cardiopulmonary health (Strong et al., 2005). The Centers for Disease Control and Prevention (CDC) recommend that children participate in at least 60 min of moderate or vigorous physical activity daily with at least 3 days a week of

Abbreviations: BC, black carbon; BMI, body mass index; CCCEH, Columbia Center for Children's Environmental Health; CDC, Centers for Disease Control and Prevention; EC, elemental carbon; FeNO, fractional exhaled nitric oxide; GM, geometric mean; Gx2, mixed grass pollen; IgE, Immunoglobulin E; MVA, moderate-to-vigorous activity; NO, nitric oxide; NO_2, nitrogen dioxide; NYC, New York City; PAH, polycyclic aromatic hydrocarbon; PM, particulate matter; SD, standard deviation; TRAP, traffic related air pollution; Tx1, mixed tree pollen; VA, vigorous activity

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vigorous activity (Strong et al., 2005). However, increased respiratory rates and tidal volumes during physical activity may increase the effective internal dose of air pollution exposure (Oravisjarvi et al., 2011). This could be especially critical in urban environments where options for physical activity may occur near sources of higher traffic-related air pollution (TRAP) due to the structure of the built environment (Council on Sports et al., 2006). However, very little research to date has addressed the link in children between regular physical activity and pollutant exposures in urban environments.

Exposure to TRAP is associated with wheeze, cough, respiratory symptoms (Spira-Cohen et al., 2011) and childhood asthma (McConnell et al., 2006). Of particular interest is, black carbon (BC), a major indicator of TRAP exposure in urban cities and a contributor to global warming (Wallack and Ramanathan, 2009) that results from incomplete combustion of fossil fuels, biofuels, and biomass. BC exposure has been associated with increased airway inflammation in children living in urban environments (Cornell et al., 2012; Lin et al., 2011). In contrast, the well-established biomarker of allergic airway inflammation, fractional exhaled nitric oxide (FeNO) (Dweik et al., 2011), has been shown to be reduced in response to physical activity (Mendes et al., 2011). Thus, it is important to better understand the balance between the benefits of regular physical activity in children the potential harm from exposure to ambient pollutants in urban environments.

Our objective was to determine the impact of personal exposure to the pollutant BC on the relationship between physical activity and airway inflammation. First, we hypothesized that active children that live in an urban environment would have greater exposure to BC, measured with personal sampler. Second, we hypothesized that higher personal BC exposure may reduce the magnitude of protection induced by physical activity on airway inflammation. Our approach was to investigate children ages 9–14 years that live in Northern Manhattan and the Bronx, NYC in a nested study that is part of a longitudinal birth cohort.

2. Materials and methods

2.1. Study population

Study participants (n=163) were recruited from the Columbia Center for Children's Environmental Health (CCCEH) longitudinal birth cohort comprised of children living in Northern Manhattan and the South Bronx of NYC, whose non-smoking, African American and Dominican mothers were enrolled during pregnancy (Perera et al., 2003). As part of the research design for the nested cross-sectional 'parent study', participants were recruited based on age (9–14 year olds) and current asthma diagnosis (Lovinsky-Desir et al., 2014). Asthma was determined by physician diagnosis during at least one cohort study visit between ages 5–12 years (Donohue et al., 2013) and report of asthma symptoms or asthma medication use in the 12 months prior to enrollment.

Children with body mass index (BMI) ≥ the 95th percentile for age and sex were classified as 'obese'. Children were recruited across all 4 meteorological seasons. Complete data on physical activity, personal BC measures, FeNO and allergic sensitization (an important covariate for examination of FeNO) was available for n=129 children that were included in this study (Fig. 1). The longitudinal birth cohort study is conducted in accordance with Columbia University Institutional Review Board guidelines and informed consents and assents were obtained.

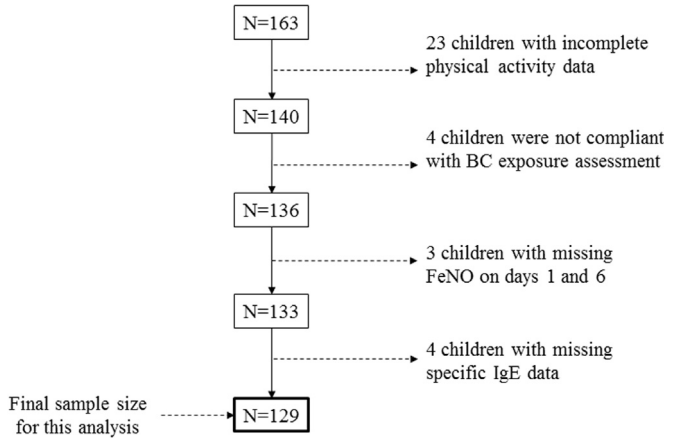

Fig. 1. *Schematic representation of sample size.* Of the 163 children enrolled in the parent study, 23 children had incomplete physical activity data, 4 children did not meet compliance standards for wearing personal BC exposure equipment, 3 children had missing FeNO measurements on both sampling days and 4 children did not have specific IgE data yielding a final sample size of 129 children for the current analysis. BC: black carbon, FeNO: fractional exhaled nitric oxide, IgE: Immunoglobulin E.

2.2. Physical activity assessment

All study participants wore an accelerometer (Actical, Philips Respironics, Bend, OR) continuously on the non-dominant wrist for 6 consecutive days (Fig. 2) and integrated measures of gross motor activity were measured in 1-min epochs. Data collection began and ended on a weekday in order to capture both weekday and weekend activity. To account for having collected only partial activity data on the first and last days we used only the 5 intervening consecutive days with full 24-h of data for characterization of physical activity (Rundle et al., 2009).

Physical activity was characterized based on the CDC recommendation that children participate in 60 min or more of moderate-to-vigorous physical activity (MVA=moderate+vigorous activity) each day and vigorous activity (VA) on at least 3 days per week (http://www.cdc.gov/physicalactivity/everyone/guidelines/children.html). Using the continuous accelerometer data, we characterized children into 3 groups: 1) 'MVA+VA' if they had ≥60 min of MVA each day and ≥10 min of VA on at least 3 days, 2) 'MVA only' if they had ≥60 min of MVA each day but did not have ≥10 min of VA on at least 3 days, and 3) 'non-active' if they had <60 min of MVA on any one day. In multivariable linear regression models, due to the smaller sample sizes in the 2 active groups, we combined the MVA+VA and MVA only groups, yielding a dichotomized predictor variable, 'active' versus 'non-active'.

2.3. Personal black carbon (BC) monitoring

Personal exposure to BC was measured over two 24-h periods at the beginning and end of the 6-d activity-monitoring period (Fig. 2). Children carried a MicroAeth (Model AE51, Magee

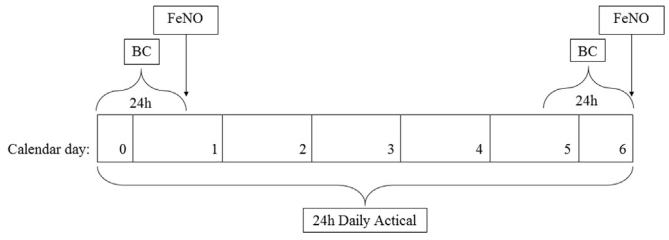

Fig. 2. *Sampling scheme for actical, BC, and FeNO collection.* BC: black carbon, FeNO: fractional exhaled nitric oxide.