International Journal of Hygiene and Environmental Health xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

International Journal of Hygiene and Environmental Health

journal homepage: www.elsevier.com/locate/ijheh

Prenatal exposure to environmental pollutants and child development trajectories through 7 years

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ARTICLE INFO

Keywords:
Prenatal exposure
Long-Term cognitive development
Air pollution
Pesticides
Mold
Household pollutants

ABSTRACT

Background: Prenatal exposure to environmental pollutants such as mold, lead, pesticides, tobacco, and air pollutants has been suggested to impair cognitive development. Evidence is needed from longitudinal studies to understand their joint impact on child development across time.
Objective: To study associations between exposure to indoor environmental pollutants or outdoor air pollution during pregnancy and offspring cognitive development trajectories through 7 years.
Methods: We included 718 Mexican mother-child pairs. Prenatal exposure to indoor environmental pollutants (mold, ventilation, pesticides, tobacco smoke, and use of vidiartred clay pots) was self-reported by the mothers and integrated into an index, or objectively measured in the case of outdoor air pollutants (nitrogen oxides, benzene, toluene, and xylene). Child global cognitive development was measured at 12, 18, 60, or 84 months. Using Latent Class Growth Analysis, we identified three developmental trajectories (positive = 108, average = 362, low = 248). We used multinomial logistic models to test associations between environmental pollutant score (EPS) or outdoor air pollutants, and cognitive development trajectories.
Results: After adjustment for sociodemographic covariates, EPS was associated with the average (OR = 1.26 95%CI = 1.01, 1.55) and low (OR = 1.41 95%CI = 1.11, 1.79) trajectories compared to positive; where a unit increase in EPS means an additional prenatal exposure to a pollutant. There was no association between outdoor air pollutants and cognitive development trajectories.
Conclusion: Children of women who reported higher exposure to indoor environmental pollutants during pregnancy were more likely to follow worse developmental trajectories through 7 years. These results support the development and testing of interventions to reduce exposure to environmental pollutants during pregnancy and early childhood as a potential strategy to improve long-term cognitive development.

1. Introduction

Pregnant women, fetuses, and infants are particularly susceptible to environmental pollutants (EP) that alter development and can have long lasting consequences for children's long-term health and intellectual achievement (Dora et al., 2015; Grandjean and Landrigan, 2006; Jurewicz et al., 2013a; Liu and Lewis, 2014; Plunkett, 2007; Saunders and Dziegielewska, 2007). Prenatal exposure to lead (Liu and Lewis, 2014; Ris, 2003; Tong, 1998), molds (Anyanwu et al., 2003; Jedrychowski et al., 2011), pesticides (Perera et al., 2005), and smoke from tobacco, open fires, or cooking (Munroe and Gauvain, 2012; Polanska et al., 2013) have been negatively associated with long-term health and development. Research has also identified exposure to outdoor air pollutants, such as nitrogen oxides and volatile compounds produced by motor vehicles or industry, as potentially impairing cognitive development (Chiu et al., 2013; Liu and Lewis, 2014), although

Abbreviations: EP, environmental pollutants; EPS, indoor environmental pollutants score; LCGA, latent class growth analysis; IRB, institutional review board; NO2, nitrogen dioxide; NOX, nitrogen oxide; BTX, volatile compounds Benzene, Toluene, and Xylene; BSID, Bayley Scales of Infant Development; MSCA, Scales of Children's Abilities; WASI, Wechsler Abbreviated Scale of Intelligence; HOME, Home Observation for Measurement of the Environment; mo, months

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https://doi.org/10.1016/j.ijheh.2018.04.004
Received 8 November 2017; Received in revised form 27 March 2018; Accepted 11 April 2018
1438-4639/

Please cite this article as: Gonzalez-Casanova, I., International Journal of Hygiene and Environmental Health (2018), https://doi.org/10.1016/j.ijheh.2018.04.004

more studies are needed (Suades-González et al., 2015).

Prenatal exposure to indoor and outdoor EP may lead to abnormalities in higher brain functions associated with inadequate positioning of the neurons during development, leading to subsequent impairment in synaptogenesis, as observed in neurological diseases (Suades-González et al., 2015) such as attention deficit and hyperactivity disorder (ADHD) (Tomasi and Volkow, 2012) and autism (Maximo et al., 2014). However, only a few studies have assessed the longitudinal impact that these EP could have on the development of healthy children. Most evidence of this association comes from animal models, cross-sectional studies, or cohort studies with a single measurement of development (Jang et al., 2012; Kundakovic and Champagne, 2011; Sadowski et al., 2014; Schantz and Widholm, 2001; Tian et al., 2010). Moreover, these studies have assessed individual effects of specific pollutants, and failed to capture the potential combined impact of exposures that often cluster together. To our knowledge, no study has looked at the association of prenatal exposure to smoke, lead, indoor air and outdoor air pollution and other EP, individually and collectively, with developmental trajectories through the school years. Challenges in conducting this research relate to both the assessment of exposure to EP during pregnancy and the challenge of obtaining repeated measurements of cognitive development throughout childhood. For this analysis, we used information from a Mexican birth cohort to identify cognitive developmental trajectories, and assess if maternal exposure to EP during pregnancy was associated with children's cognitive development through 7 years of age.

2. Methods

2.1. Study design and sample selection

We conducted a longitudinal observational study. The data originates from a randomized control trial of Prenatal Omega-3 Supplementation on child Growth and Development (POSGRAD) (Ramakrishnan et al., 2010). Mothers were enrolled between the 18th and the 22nd week of gestation in Cuernavaca, Mexico. For this analysis, we included all singleton births whose mothers had completed the environmental exposures questionnaire during pregnancy, had information about outdoor air pollutants near their homes, and had measures of cognitive development for at least one time point (12, 18, 60, or 84 mo).

Participation in the study was voluntary. Mothers provided informed consent for themselves and their children to participate in the study. Children provided verbal assent to participate in the study at 7 years. The study was approved by the Emory University IRB and the Ethics Board of the National Institute of Public Health in Mexico.

2.2. Environmental pollutants assessment

Information on behaviors or household conditions that potentially associated with increased exposure to mold, lead, pesticides, tobacco smoke, indoor air pollutants, and other sources of EP was collected during prenatal home visits using a questionnaire. Initially, the focus of the questionnaire was to identify exposures associated with allergies or asthma. We selected the relevant questions based on recent reviews of the association between early exposure to EP and child cognitive development (Jurewicz et al., 2013a,b; Vieira, 2015). The questions included in the index are described in the statistical analysis section.

Items were scored so that behaviors considered to increase exposure to EP received positive scores. The scores were as follows: Was there mold, slime, or humidity on walls or floors in the last month (yes = 1, no = 0); type of stove (2 = wood or oil, 1 = gas, 0 = electric); uses extractor or ventilator when cooking (yes = 0, no = 1); window remains open during the day (yes = 0, no = 1), used pesticides at home (yes = 1, no = 0) ; mother currently smokes (yes = 1, no = 0); someone else smokes in the home (yes = 1, no = 0); and prepares food using clay pots (because of lead content; yes = 1, no = 0). Items with a variability of less than 3% where excluded from the final EPS.

2.2.1. Measurement of atmospheric pollutants

We developed area-specific land use regression (LUR) models of nitrogen oxides (NO2, NOX) and volatile organic compounds (BTX) to estimate residential exposure during pregnancy. Ambient levels of air pollutants were measured with Ogawa and 3 M passive samplers during periods of 2 week in 60 different sites throughout the city of Cuernavaca. The samplers were positioned outdoors, near the participants' homes (e.g. roofs, light-poles) following standard protocols. The measurements were validated against potential predictor variables such as traffic, land use, topography, population density and distance to avenues. These models explained 60–70% of the variability of measured air pollution levels. Levels outside participants' homes at the time of the application of the environmental pollutants questionnaire were estimated using LUR by fitting a predictive linear model including these predictor variables.

2.3. Cognitive development measurements

The Bayley Scales of Infant Development (BSID) II were administered at 12 and 18 mo. The BSID-II is used widely to assess child development in both clinical and research settings and is sensitive to early exposures such as environmental pollutants (Black and Matula, 2000).

The McCarthy Scales of Children's Abilities (MSCA) Test (Hayes, 1981) was administered at 5 y. This tool is used to assess cognitive development of preschool children. Good predictive validity of the general cognitive scale index of the MSCA has been demonstrated through significant correlation with achievement tests (Axelrod, 2002; Carvajal et al., 1993; Clements, 1965; Hays et al., 2002).

The Wechsler Abbreviated Scale of Intelligence (WASI) was administered at child age 7 y. It is a short version of the commonly used Wechsler Intelligence Scale for Children. It produces three different scales: verbal, performance, and full IQ test (Axelrod, 2002; Carvajal et al., 1993; Clements, 1965; Hays et al., 2002).

We used the Spanish versions of the three instruments, which have been previously adapted and used with Mexican infants and children (Schnaas et al., 2006; Torres-Sanchez et al., 2013; Vazquez-Salas et al., 2014). All instruments were administered by trained psychologists in a quiet place at the study headquarters. The exact age at measurement was calculated by subtracting the date of birth to the date of the interview and used to adjust the scores.

2.4. Other covariates

Extensive socio-demographic information, obstetric history, anthropometric measurements and dietary intakes were collected at enrollment (Ramakrishnan et al., 2010). A socioeconomic status (SES) index was developed using principal components analysis based on an income and assets questionnaire that has been used for other population studies in Mexico (Resano-Perez et al., 2003). Maternal schooling (in years) was self-reported at enrollment. Maternal intelligence was assessed using the Raven progressive matrices tests (Raven, 2000) which is a non verbal test that is used to measure abstract reasoning. It was specifically developed as an "easy- to- administer, easy- to interpret" tool to assess fluid intelligence and has been validated for use in different settings (Raven, 2000). The version used for this study included 3 sections of 12 problems each for a maximum possible score of 36. The test was applied by a trained psychologist in a quiet room at the study clinic (Ramakrishnan et al., 2010).

Data on birth outcomes, child anthropometry and infant and young feeding practices, including breastfeeding, were collected for all offspring (Ramakrishnan et al., 2010). The Home Observation for Measurement of the Environment (HOME) questionnaire was used to assess household stimulation and learning environment between 6 and 12