Prenatal concentrations of Perfluoroalkyl substances and early communication development in British girls

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ABSTRACT

Perfluoroalkyl substances (PFAS), found in many household products and classed as endocrine disrupting chemicals, can be transferred through the placenta and are associated with multiple developmental deficits in offspring. Using data from the Avon Longitudinal Study of Parents and Children (ALSPAC), we investigated the association between intrauterine exposure to PFAS and early communication development in 432 mother-daughter dyads at 15 and 38 months of age. Concentrations of perfluorooctane sulfonate (PFOS), perfluorooctanoate (PFOA), perfluorohexane sulfonate (PFHxS), and perfluorononanoate (PFNA) were measured in maternal serum collected during pregnancy. Early communication development was measured with the ALSPAC-adapted MacArthur Communicative Development Inventories for Infants and Toddlers. The infant questionnaire measured verbal comprehension, vocabulary comprehension and production, nonverbal communication, and social development. The toddler questionnaire measured language, intelligibility, and communicative sub-scores. Multivariable linear regression was used to examine associations between each PFAS exposure and each communication sub-scale score. The association between maternal PFAS concentrations and early communication development at 15 and 38 months of age varied by maternal age at delivery. In daughters of younger mothers (< 25 years of age), every 1 ng/mL of PFOS was associated with a 3.82 point (95% confidence interval (CI): −6.18, −1.47) lower vocabulary score at 15 months and a 0.80 point (95% CI: −1.74, 0.14) lower language score at 38 months. Prenatal exposure to select PFAS was positively and negatively associated with communication development among girls, with inconsistent pattern of association across all measured PFAS and endpoints.

1. Introduction

Perfluoroalkyl substances (PFAS) comprise a class of man-made endocrine disrupting chemicals (EDCs) involved in the production of fluoropolymers found in many household consumer products. PFAS are used to make protective coatings on textiles, furniture, food packaging, and nonstick cookware. Exposure to PFAS is common and can occur through water, indoor dust, and air [1]. PFAS are found in circulating blood, breastmilk, cord blood and can be transferred through the penetrable placenta during pregnancy [2–4]. The most commonly studied PFAS include perfluorooctane sulfonate (PFOS), perfluorooctanoate (PFOA), perfluorohexane sulfonate (PFHxS), and perfluorononanoate (PFNA).

The risk of potential adverse health effects from PFAS has led to an industry phase out and replacement of some of these chemicals in the U.S. and Europe; however, PFOS is still commonly manufactured in China [5–7]. PFAS are a public health concern due to their persistent nature and ability to bioaccumulate in body tissue [5,8–10]. The estimated mean serum elimination half-life for PFOS, PFOA, and PFHxS is 5.4, 3.8, and 8.5 years, respectively [11].

Evidence suggests that prenatal exposure to various EDCs may be associated with certain cognitive and behavioral problems in childhood [12–17]. A fetus can be susceptible to developmental effects of PFAS associated with disruption of estrogenic activity [18,19].

PFOS and PFOA exposure during critical windows of development can affect neurodevelopment of a pregnant mother’s offspring. In mice, neonatal PFOS and PFOA exposure causes altered levels of essential proteins needed for brain development, specifically affecting the...
between the ages of 8 and 13 years. Cases were de-
ted from the ALSPAC cohort who returned at least two puberty questionnaires
ated from the ALSPAC Ethics and Law Commit-
t. The study website contains additional details for all available
The present study used data from 448 mother-daughter dyads
2.2. Data collection
An adaptation of the MCDI was used to assess early communication development at 15 and 38 months. The ALSPAC adaptation of the MCDI includes a selection of questions from the original MCDI and was modified to include words used in England. The MCDI is a parent

2. Methods

2.1. Study Population

The Avon Longitudinal Study of Parents and Children (ALSPAC) is a
hippocampus, which is primarily responsible for memory and learning
[20]. In humans, the association between prenatal PFAS exposure and
early cognitive development is unclear. A cross sectional analysis of
data from the U.S. National Health and Nutrition Examination Survey
(NHANES) has demonstrated that higher exposure to PFAS is associated
with an increased odds of attention deficit/hyperactivity disorder
(ADHD) in children 12–15 years of age [13]. However, two previous
reports from the Taiwan Birth Panel Study and the Danish National
birth cohort, have found inconsistent associations between prenatal
PFOS and PFOA exposure and neurodevelopment. Specifically, using
mother-reported structured questionnaires for children at 6 and
18 months of age, the Danish National Birth Cohort did not find a
significant association between prenatal PFOS or PFOA exposure and
neurodevelopment [21]. In contrast, using Comprehensive Devel-
Development Inventory for Infants and Toddlers at 2 years of age, the Taiwan
Birth Panel Study concluded that prenatal exposure to PFOS and PFOA
may be negatively associated with neurodevelopment in children [12].
Additional research using longitudinal biomarker and cognitive func-
tion data to evaluate the association between early life exposure to
PFAS and cognitive development in young children is warranted [22].

The current study aimed to investigate whether maternal concen-
trations of PFOS, PFOA, PFHxS, and PFNA during pregnancy was
associated with deficits in development of communication skills at 15 and
38 months of age in British girls using data from the Avon Longitudinal
Study of Parents and Children (ALSPAC). We also examined whether the association between maternal PFAS exposure and communication development varied by maternal age at delivery or
maternal education. Data used for this study was originally selected for
a nested case-control study examining environmental effects on me-
narche [23].

Concentrations of PFOS, PFOA, PFHxS, and PFNA were measured
from maternal serum samples collected during pregnancy at a median
gestational age of 15 weeks. Maternal serum concentrations were used
as a proxy for fetal exposure. Blood samples were transferred under
controlled conditions to the National Center for Environmental Health
of the Centers for Disease Control and Prevention in the United States
for analysis. A previous study has described methods used to measure
analytes in the serum samples [28]. Limits of detection were 0.2 ng/mL
for PFOS, 0.1 ng/mL for PFOA, 0.1 ng/mL for PFHxS, and 0.08 ng/mL
for PFNA. Quality control measures to ensure calibration were im-
plemented using standards, reagent blanks, and study samples. Preci-
sion of measurements for the analytes, as relative standard deviation,
ranged from 8 to 13%.

2.4. Statistical analysis

To investigate the association between maternal PFAS concentra-
tions and each early communication sub-score, stratum-weighted linear
regression models were developed with the communication measures
and PFAS concentrations as continuous variables. Crude associations
between PFAS analytes and early communication development scores
were first examined using univariate regression analysis. A set of
potential confounding variables was selected a priori for consideration
in multivariable regression models. The final model was achieved
through backwards elimination of insignificant variables in a hierarch-
ical manner [29]. The following variables were controlled for in the
final model: parity, maternal age, maternal education, maternal smok-
ing status during the first three months of pregnancy, and gestational

Written informed consent for participation in the study.

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