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Association between perfluorinated compound concentrations in cord serum and birth weight using multiple regression models

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ABSTRACT

The effects of exposure to the perfluoroalkyl and polyfluoroalkyl substances (PFASs) perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) on birth weight have been examined in several studies, but other PFASs have not been considered. We conducted a cross-sectional survey of newborns in Seoul, South Korea, collecting 118 serum samples, for 85 of which we had a full range of information. We conducted multiple regression analyses to examine the association between nine PFAS concentrations in cord serum and birth weight. Seven PFASs were found in cord serum, PFOA and PFOS being dominant, with mean concentrations of 1.11 and 0.87 ng/mL, respectively. The adjusted birth weight changes (natural log) were −0.14 (95% confidence interval −0.33–0.03) for PFOS and −0.03 (95% confidence interval −0.25–0.18) for PFOA. None of the PFASs were statistically associated with birth weight in this population.

1. Introduction

Perfluoroalkyl and polyfluoroalkyl substances (PFASs), which are currently regarded as emerging contaminants, are a family of substances made primarily of carbon and fluorine atoms. They have been used for more than 60 years in numerous industrial products and consumer products, such as fabrics, leather, fire-fighting foam, and food packaging, because of their stable properties [1–3].

A large amount of research on PFAS exposure in humans has been reported, and widespread exposure to PFASs has been documented in adults, children, and even infants [4–14]. Although many studies have shown higher human exposure to PFASs over 30 ng/ml as mean value [4,5], a decreasing trend in human exposure to PFASs has recently been reported in the USA and Europe [15–17], which seems to be related to efforts to phase out perfluorooctane sulfonate (PFOS) and PFOS-related chemicals, because they are now included in the Stockholm Convention. For example, the PFOS and perfluorooctanoic acid (PFOA) levels from Norwegian residents have been reduced to about 50% in human blood in 2006 compare with around year of 2000 [15]. Also, the approximate geometric means of PFOS in American Red Cross adult blood were declined 60% from 2000 to 2006 [17]. Lastly, concentrations of PFOS in U.S. population decreased during the survey periods between 1999 and 2000 and 2007–2008 with 63% and 49% for females and males, respectively [16]. Meanwhile, a study of archived human samples in East Asia did not show a decreasing trend [14], and 13-fold increases for PFOS and 6.3-fold for PFOA concentrations was found between 1999 and 2002 in China, because of the continuous production and importation of PFOS and PFOA [18]. Research into human exposure to PFASs is still, therefore, required.

It is suggested that human exposure to PFASs can occur through food, dust or biotransformation of commercial fluorochemicals as direct or indirect sources [19–23]. It has also been suggested that prenatal and postnatal exposure to PFASs occurs through cord blood [24,25] and breast feeding [10,26,27], respectively.

Adverse health effects on development and reproductivity, such as decreased birth weight, gestational length, and postnatal survival during early life, from PFOS and PFOA exposure have been found in laboratory animal exposure studies [28–30]. Recent studies applying the Navigation Guide Methodology have demonstrated the adverse effect of PFOA on fetal growth in animals and human [31–33].

Abbreviations: CI, confidence interval; MDLs, method detection limits; PFASs, perfluoroalkyl and polyfluoroalkyl substances; PFBS, perfluorobutane sulfonate; PFHxS, perfluorohexane sulfonate; PFHpS, perfluoroheptane sulfonate; PFOS, perfluorooctane sulfonate; PFOA, perfluorooctanoic acid; PFNA, perfluorononanoic acid; PFDA, perfluorodecanoic acid; PFUnA, perfluoroundecanoic acid; PFDoA, perfluorododecanoic acid.

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Table 1
Overview of studies of the associations between perfluoroalkyl and polyfluoroalkyl substances (PFASs) and birth weight.

Author	Location	Sample description (No.)	PFAS[†] median concentration (range)[a]	Study method	Results
Andersen et al., [38]	Denmark	Maternal plasma (1118)	PFOS: 33.4 (6.4–106.7) PFOA: 5.21 (0.5–21.9)	Multiple linear regression	[per ng/ml unit β (95% CI)] PFOS: −1 g (−3.1 to 1.0) PFOA: −12.8 g (−24.5 to −1.2)[*]
Apelberg et al., [34]	USA	Cord serum (293)	PFOS: 5 (<LOD–34.8) PFOA: 1.6 (0.3–7.1)	Multiple linear regression	[per ln-unit β (95% CI)] PFOS: −69 g (−149 to 10) PFOA: −104 g (−213 to 5)
Fei et al., [35]	Denmark	Maternal plasma (1388)	PFOS: 35.3[b] (6.4–106.7) PFOA: 5.6[b] (LLOQ–41.5)	Multiple linear regression	[per ng/ml unit β (95% CI)] PFOS: −0.46 g (−2.34 to 1.41) PFOA: −10.63 g (−20.79 to −0.47)[*]
Hamm et al., [39]	Canada	Maternal serum (252)	PFOS: 7.8 (<LOD–35) PFOA: 1.5 (<LOD–18) PFHxS: 0.97 (<LOD–43)	Multiple linear regression	[per ln-unit β (95% CI)] PFOS: 31.3 g (−43.3 to 105.9) PFOA: −37.4 g (−86.0 to 11.2) PFHxS: 21.9 g (−23.4 to 67.2)
Maisonet et al., [42]	England	Maternal serum (447)	PFOS: 19.6 (3.8–112.0) PFOA: 3.7 (1.0–16.4) PFHxS: 1.6 (0.2–54.8)	Multiple linear regression	[β(95% CI)] PFOS: reference [<16.6][d] −111.71 g (−208.24 to 15.17) [16.6–23.0][d] −140.01 g (−238.14 to −41.89)[*] [>23.0][d] PFOA: reference [<3.1][d] −56.81 g (−153.05 to 39.43) [3.1–4.4][d] −133.45 g (−237.37 to −29.54)[*] [>4.4][d] PFHxS: reference [<1.3][d] −9.10 g (−108.08 to 89.88) [1.3–2.0][d] −107.93 g (−206.18 to −9.69)[*] [>2.0][d]
Monroy et al., [36]	Canada	Maternal serum (101) Cord serum (105)	Maternal serum PFOS: 14.54 (9.19–20.22) PFOA: 1.81 (1.33–2.64) PFNA: 0.69 (0.542–0.87) PFHxS: 1.62 (1.33–2.66) Cord serum PFOS: 6.08 (3.92–9.11) PFOA:1.58 (1.09–2.37) PFNA: 0.72 (0.61–0.80) PFHxS: 2.07 (1.46–2.77)	Multiple linear regression	No correlation between maternal and cord serum PFAS and birth weight.
Kim et al., [40]	Korea	Maternal serum (44) Cord serum (43)	Maternal serum PFOS: 2.93 (2.08–4.36)[c] PFOA: 1.46 (1.15–1.91)[c] PFHxS: 0.55 (0.46–0.85)[c] PFTrDA: 0.24 (0.17–0.31)[c] Cord serum PFOS: 1.26 (0.81–1.82)[c] PFOA: 1.15 (0.95–1.86)[c] PFHxS: 0.34 (0.27–0.51)[c] PFTrDA: 0.47 (0.36–0.73)[c]	Partial correlation analysis	No significant association were observed between concentrations of PFCs in blood of mothers or the fetus and birth weight
Savitz et al., [41]	USA	Maternal serum (106)	PFOA:7.7 (4.9–17.2)[c] for Study 1 13.4 (5.6–61.2)[c] for Study 2	Multiple linear regression	[per 100ng/mL unit β (95% CI)] 14.80 g (−43.28 to 13.68) for Study 1 −9.14 g (−20.30 to 2.02) for Study 2
Whitworth et al., [43]	Norwegian	Maternal plasma (901)	PFOS:13.0 (10.3–16.6) PFOA: 2.2 (1.7–3.0)	Multiple linear regression	[β(95% CI)] PFOS: reference [<10.27][e,f] −0.08 (−0.29 to 0.13) [10.27–12.97][e,f] −0.17 (−0.39 to 0.05) [12.98–16.58][e,f] −0.18 (−0.41 to 0.05) [≥16.59][e,f] PFOA: reference [<1.65][e,f] −0.06 (−0.28 to 0.16) [1.65–2.24][e,f] −0.08 (−0.32 to 0.16) [2.25–3.03][e,f] −0.21 (−0.45 to 0.04) [≥3.04][e,f]

ND: Not detected.
CI: Confidence interval.
[*] $p < 0.05$ (statistically significant).
[†] PFHxS = perfluorohexane sulfonate; PFOS = perfluorooctane sulfonate; PFOSA = perfluorooctane sulfonamide; PFOA = perfluorooctanoic acid; PFNA = perfluorononanoic acid; PFTrDA = perfluorotridecanoic acid.
[a] Units: ng/mL.
[b] Mean concentration.
[c] Interquartile range.
[d] Tertiles of the analyte concentrations (ng/mL).
[e] Quartiles of the analyte concentrations (ng/mL).
[f] Z scores for birth weight.