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"Effects of prenatal exposure to environmental pollutants on birth weight and child weight gain"

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Abstract
The first thousand days of a child's life is a critical period for pollutant exposure, as the fetus and child are especially vulnerable to environmental pollutants. This review presents an overview of studies carried out on prenatal exposure to environmental pollutants and their effects on birth weight and childhood weight gain from 2019 to 2022. The total number of studies evaluated was 20, with 19 being birth cohort studies. Nine studies (45%) observed a lower birth weight, and 35% (7) found an association with increased childhood weight gain. The main pollutants evaluated were persistent organic pollutants (6), mainly associated with childhood weight gain; metals (7), mainly associated with low birth weight; and phthalates (6), which reduced birth weight and weight gain but also increased childhood weight gain. In conclusion, there is evidence that prenatal and early childhood exposure to environmental pollutants can influence birth weight and child weight gain.

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Introduction

One of the most significant challenges for health and sustainable development in the 21st century is the fight against non-communicable chronic diseases, due to the damage caused to human health and socioeconomically, especially in low- and middle-income countries [1]. Cancer, diabetes, cardiovascular and lung diseases account for 72% mortality rate worldwide [1]. Obesity, arterial hypertension, dyslipidemia are among the risk factors for cardiovascular diseases and diabetes, which together make up the metabolic syndrome associated with these diseases [2] (Figure 1).

Over 1 billion people worldwide are obese, 39 million being children [3]. Obese children experience breathing difficulties, increased risk of hypertension, insulin resistance [4], also being at greater risk of obesity and premature death in adulthood [34].

The period from pregnancy to age 3 is when children are most susceptible to environmental influences and pollutants can influence birth and child weight gain throughout the growth and development [34]. The exposure to environmental pollutants has been considered a contributory obesity and weight gain cause, besides known causes such as diet, physical activity, and genetic susceptibility [5–7].

The Developmental Origins of Health and Disease (DOHaD) hypothesis suggests that environmental stressors during pregnancy can result in adverse health effects later in life [29]. Early life represents the largest window of vulnerability for developmental disruptions in physiology with long-term and potentially lifelong consequences [8]. Children with low birth weight may experience an increased risk for cardiovascular diseases and obesity in adulthood [36]. Birth weight and childhood weight gain are associated with the health of both children and adults [34]. Environmental risks have an impact on children's health and development from conception through childhood and adolescence into adulthood, as early-life disorders are linked to adult health [37].

This review explores the association between environmental pollutants and birth weight and childhood weight gain. It provides an overview of studies conducted from birth to age 12, along with a brief description of key findings from investigations on metals, POPs, phthalates, and pyrethroids.

Abbreviations

LGA	Large for gestational age
IQR	Interquartile range
Q2	Second quartile
BW	Birth weight
WG	Weight gain
p	p value
As	Arsenic
Cd	Cadmium
Mn	Manganese
Pb	Lead
Se	Selenium
Hg	Mercury
SD	Standard deviation
CI	Confidence intervals
GM	Geometric mean
OR	Odds ratio
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
PFAS	Perfluoroalkyl substances
PFOS	Perfluorooctanesulfonic acid
PFOA	Perfluorooctanoic acid
PCB	Polychlorinated biphenyl
BMI	Body mass index
Q2	Second quartile
PFNA	Perfluorononanoic acid
POPs	Persistent organic pollutants
HCH	Hexachlorocyclohexanes
HCB	Hexachlorobenzene
OC	Organochlorine compounds
PBDEs	Polybrominated diphenyl ethers
DEHP	di(2-ethylhexyl) phthalate
MEHHP	Mono(2-ethyl-5-hydroxyhexyl) phthalate
BP3	Benzophenone-3
trans	DCCA-trans-3-(2,2,-dicolorvinyl)-2,2-dimethyl-cyclopropane carboxylic acid
Ref	Reference
F	Females
M	Males
USA	United States of America
SAGER	Sex and Gender Equity in Research

Methodology

Only original articles published from 2019 to 2022 investigating prenatal exposure (maternal) to environmental pollutants (no specific class) and their effects on birth weight and weight gain of children from birth to 12 years old.

Inclusion criteria: human studies; population studies (descriptive and analytical epidemiologic methods). Exclusion criteria: animal studies, non-English studies, laboratorial or experimental studies and studies that did not examine the aforementioned relationships. The search was conducted on databases (Cochrane, Science Direct, PubMed, and Medline) using specific keywords: "prenatal exposure," or "environmental pollutants," and "birth weight," and "childhood weight gain." We used the Newcastle–Ottawa Scale (NOS) to assess the methodology quality of individual studies because all included studies were observational epidemiological studies.

Results

The review investigating the effects on the child's birth weight (BW) and weight gain (WG) found 20 studies, 45% (9 studies) on low BW and 35% (7 studies) on child increase WG. These include articles from nine countries, 60% (12) of the studies were from the China and the United States of America, and the remaining 40% (8) were spread among Germany, Canada, Japan, Spanish, Korea, Bangladesh, and South Africa. We found 6 studies evaluating persistent organic pollutants (DDT, DDE, PCB, HCB, HCH, PBDE, PFAS), 7 studies evaluating metals (lead, mercury, manganese, cadmium, arsenic, selenium), 6 studies evaluating phthalates, 1 study evaluating pyrethroids. Among 20 studies found, 19 were birth cohort studies. To obtain the outcomes, some adjustment covariates were taken into account.

The table below summarizes the evaluated studies regarding the pollutants studied, the study designs, the context, the age group of the children, the covariate adjustment.

Results of the quality assessment of eligible studies showed that all studies (n = 20) in this review obtained high NOS scores (seven stars or above). Therefore, the methodological quality of included studies was good, providing a reliable guarantee for estimating the association between prenatal exposures and their effects on birth weight and childhood weight gain (Table 1).

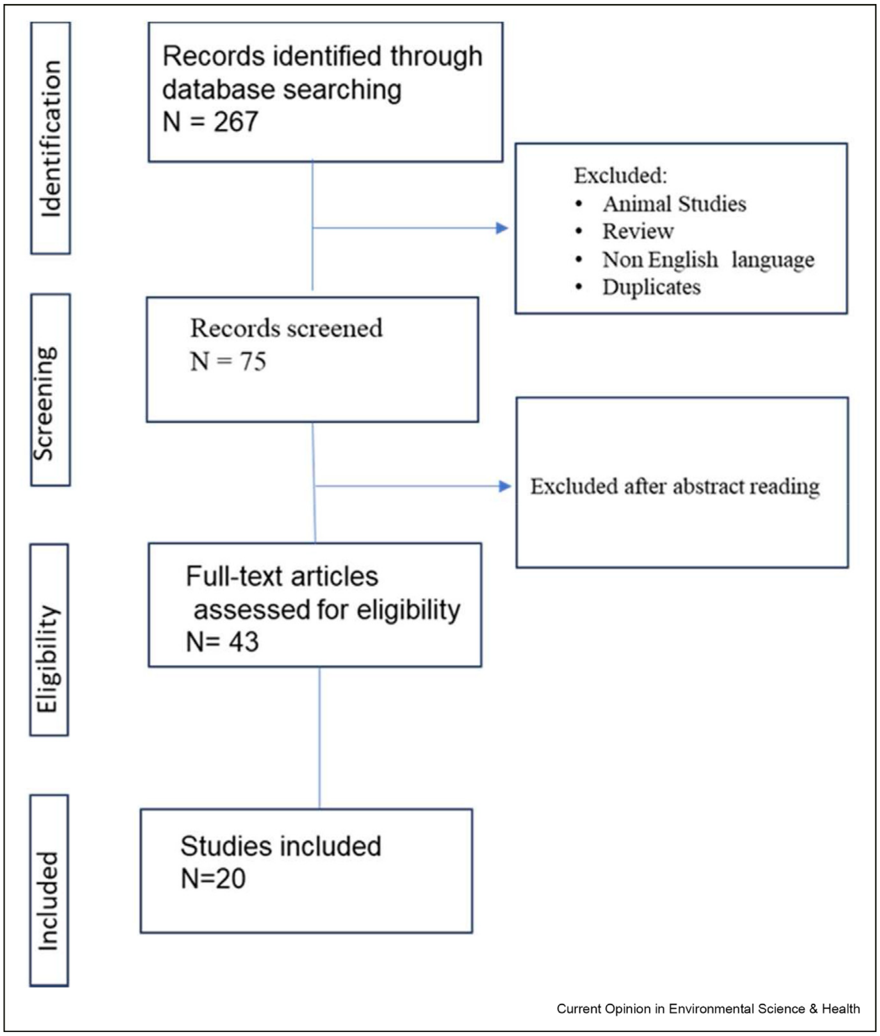
Effects on birth weight

Most conducted studies (10) have reported decreased birth weight when exposed to environmental pollutants. The metals (cadmium, lead, mercury, arsenic, selenium) are the main pollutants associated to low birth weight [9,11–14]. Exposure to Manganese and PCB has been associated increased birth weight [12,19]. According to Table 2 below.

Effects of environmental pollutants on childhood weight gain

Persistent organic pollutants (DDE, DDT, HCH, HCB, PFOA, PBDE) [7,25,27,31], are the main pollutants associated to increased weight gain in childhood. Three studies found an association between

Figure 1



Flow chart of study selection process.

phthalate exposure and childhood weight gain [28–30]. Exposure to pyrethroid pesticides [32], phthalates [28], lead and cadmium [22,23] appear to be associated with lower weight gain in children. Table 3 presents studies that evaluated prenatal and childhood exposure to environmental pollutants and their effects on weight gain.

Discussion

Among the ten studies that assessed birth weight and prenatal exposure to environmental pollutants, the maternal concentrations of metals (lead, cadmium, mercury, arsenic, and selenium - 5 studies), phthalates (3 studies), and PFAS (1 study) were inversely proportional to birth weight in 9 studies. The meta-analysis conducted by Yang [16] demonstrated a positive and significant association between PFOS exposure and the risk of low birth weight, particularly in America and Asia. Among the studies that evaluated birth weight, two studies associated prenatal exposure with increased birth weight. In one study [19], PCBs were evaluated and linked to increase BW. In the other [12], lead, cadmium, selenium, and manganese were evaluated, however, only manganese was associated with increased BW.

Among the studies that evaluated child weight gain (10), all assessed prenatal exposure to environmental pollutants, and two of these studies also evaluated pollutant exposure during childhood [23,25]. The

Table 1

Number (N) of studies included by agent and type of evaluation.

Environmental agent	Design of study	Region or country	Age group	Covariate adjustment
Metals (Mn, Ar, Hg, Pb, Cd, Se) N = 7	Cohort N = 6 Cross-sectional N = 1	Japan N = 1 USA N = 2 Canada N = 1 Korea N = 1 China N = 1 Bangladesh N = 1	From born to 10 age	Maternal age, alcohol and smoking consumption and exposure, occupation, residence, education, clinical data, parity, pre-pregnancy BMI, Season of conception
Phthalates N = 6	Cohort N = 6	Germany N = 1 Spanish N = 2 USA N = 1 China N = 2	From born to 12 age	Gestational age, occupation, residence, education, pre-pregnancy BMI, Parity, infant sex, breastfeeding duration, smoking, alcohol consumption, physical activities
POPs N = 6	Cohort N = 6	Germany N = 1 USA N = 3 China N = 3	From born to 12 age	maternal age, pre-pregnancy BMI, weight at delivery, parity, pregnancy complications, Gestational age, marital status
Pyrethroids N = 1 Total = 20	Cohort N = 1	South Africa N = 1	From born to 5 age	Mothers age, marital status, total household income, total household size, food poverty

POPs: persistent organic pollutants including organochlorine pesticides, PBDE, PFAS; BMI: body mass index

systematic review conducted by Stratakis [26] demonstrates that DDE and HCH are linked to elevated BMI in children. Furthermore, this author categorizes DDE as “presumed” to have obesogenic effects on humans.

Among the 20 studies, all of them assessed maternal samples (urine and/or blood), two studies examined children’s samples (umbilical cord blood, urine, whole blood), and 1 study assessed both maternal and child samples. For studies using median metal concentration as metric, lead concentrations ranged from 4.37 to 5.85 μg/L, and mercury concentrations ranged from 0.58 to 1.25 μg/L. However, due to the use of different metrics across the studies, comparability between them was not possible.

The effect of environmental pollutants exposure on childhood weight gain seems to be more significantly associated with the sex in some studies. According to SAGER guidelines, it was verified that sex refers to sex assigned at birth [33]. Among the studies that evaluated birth weight (Table 2) three studies taking into account the child’s sex, two observed more significant results in girls ($p = 0.04$ and 0.33) [10,11] and one in boys ($p = 0.004$) [9]. Among the ten presented studies (Table 3), five (50%) found effects only, or more expressively, in one sex [22,23,28,29,32].

The same group of compounds may have different effects on birth weight and weight gain. Phthalates were inversely associated with birth weight and associated with high BMI trajectories in early childhood [10,15,24]. Phthalates (DEHP) may be associated with decreased weight gain at 6–12 months of age [28] and the same component may increase weight gain between 24 months and 12 years of age [28,29].

Birth weight is a determinant of child health, since children with low birth weight have a high chance of death in the first year of life [34]. Low birth weight can influence adulthood, increasing the risk of chronic diseases in adulthood, such as obesity and diabetes [34]. Newborn’s and child’s weight monitoring constitutes a measure of good health throughout life. Although this review had worked only with the weight parameter, it is important to highlight that child development goes beyond weight assessment, including neurodevelopment, growth, cognitive and emotional factors [35].

Regarding the gaps highlighted in this review, it was observed that many studies did not provide sex-stratified estimates, hindering a comprehensive summary of potential differences between sexes. Additionally, many studies did not assess the socioeconomic conditions of the participants, which could interfere with the results. The majority of studies focused on the United States of America and China, without encompassing a large part of Europe, Africa, Central and South America. Exposure does not occur with isolated chemical substances but rather with complex mixtures, due to the common sharing of sources and pathways of exposure. Pollutant exposures can exert interactive effects (synergistic or antagonistic), and further studies are needed to evaluate exposure to mixtures of environmental pollutants.

Table 2

Prenatal exposure to environmental pollutants and effects on BW.

Agent	Reference	Study setting & period	Study sample size;	Study type	Biological sample	Exposure levels & metrics	Covariate adjustment	Results
Reduced BW								
Cadmium	[12]	Japan Environment & Children's Study (JECS) (2011–2014)	93,739 mother–infant pairs	Cohort	Blood's Pregnant women second or third trimester	Median 0.66 (0,10–5.33) ng/g	Maternal age, pre-pregnancy BMI, alcohol consumption and smoking status, income, education, gestational age, sex, parity	A two-fold increase in maternal Cd concentrations (0.10–5.33 ng/g) was associated with a 14.9 g (95% CI: 11.31–18.43) decrease in BW
	[9]	Massachusetts Project Viva (1999–2002)	1391 mother–infant pairs	Cohort	Mothe's erythrocytes (first trimester)	Cd (IQR = 0.28 ng/g)	Maternal age, education, pre-pregnancy BMI, household income, smoking status, ethnicity, parity, infant sex	Each IQR increase (0.28 ng/g) was associated with a 26.6 g reduction (95% CI: –51.8–1.4) in BW
Lead	[12]	Japan Environment & Children's Study (JECS) (2011–2014)	93,739 mother–infant pairs	Cohort	Blood's Pregnant Women second or third trimester	Median 5.85 (1.20–110.0) µg/L	Maternal age, pre-pregnancy BMI, alcohol consumption and smoking status, income, education, gestational age, sex, parity	A two increase in maternal Pb concentrations was associated with a 39.8 g (95% CI: 35.50–44.10) decrease in BW
	[9]	Massachusetts Project Viva (1999–2002)	1391 mother–infant pairs	Cohort	Mothe's erythrocytes (first trimester)	IQR = 10.1 µg/L	Maternal age, education, pre-pregnancy BMI, household income, smoking status, ethnicity, parity, infant sex	Each IQR increase (10.1 ng/g) was associated with a 33.9 g decrease (IC 95%: - 65.3;- 2.5 in BW
	[14]	Canada Maternal-Infant Research on Environmental Chemicals (MIREC). 2008–2011	1857 pregnant women	Cohort	Maternal urine or blood samples (1st trimester)	GM 6,2 (1.6–41.4) µg/L	Race, education, smoking Status, infant sex, pre-pregnancy BMI	A two-fold increase in maternal Pb concentrations reduced mean birth weight by –39 g (95% CI: –69, –9)
	[13]	Children's Health & Environmental Chemicals in Korea (CHECK)	335 mother–child pairs	Cross-Sectional	Maternal urine (delivery)	Median 4.37 (0.92–92.36) µg/L	Maternal age, gestational age, infant sex, parity, delivery mode, pre-pregnancy BMI, smoking & drinking	The Ponderal index, was negatively associated with maternal urinary Pb (β = –0.23, 95% CI: –0.46;-0.07)
Mercury	[13]	Children's Health & Environmental Chemicals in Korea (CHECK)	335 mother–child pairs	Cross-Sectional	Maternal urine (delivery)	Median 1.25 (0.03–18.3) µg/L	Maternal age, gestational age, infant sex, parity, delivery mode, pre-pregnancy BMI, smoking & drinking	The Ponderal index, was negatively associated with Hg (β = –0.26, 95% CI: –0.44, –0.08)
	[11]	Initial Vanguard Study (IVS) - USA 2009–2010	125 mother–infant pairs	Cohort	Maternal blood (6 to 32 weeks)	Median 0.58 (0.11–5.32) µg/L	Maternal age, race/ethnicity, educational attainment, family income, smoking status, alcohol use, and parity	Inverse association of maternal mercury exposure (Median: 0.58 µg/L 0,11–5,32) with birth weight **in girls** p = 0,33.
Arsenic	[9]	Massachusetts Project Viva (1999–2002)	1391 mother–infant pairs	Cohort	Mothe's erythrocytes (first trimester)	As 1.1 ng/g	Maternal age, education, pre-Pregnancy BMI, household income, smoking status, ethnicity, parity, infant sex	Each IQR increase in As (1.1 ng/g) was associated with a 29.3 g (95% CI: –59.5, 1.0) decrease in BW. **(in girls p = 0.04)**

(*continued on next page*)

Table 2. (*continued*)

Agent	Reference	Study setting & period	Study sample size;	Study type	Biological sample	Exposure levels & metrics	Covariate adjustment	Results
Selenium	[12]	Japan Environment & Children's Study (JECS) (2011–2014)	93,739 mother–infant pairs	Cohort	Blood's pregnant women second or third trimester	Median 168.0 (82.8–976.0) ng/g	Maternal age, pre-pregnancy BMI, alcohol consumption and smoking status, income, education, gestational age, sex, parity	A two-fold increase in maternal concentrations was associated to a 54.8 g decrease (95% CI: 41.52, 68.11) in BW
Phthalates	[15]	The Infant Development and the Environment Study (TIDES) 2010–2012, USA	780 participants	Cohort	Maternal urine & blood (11 & 32 weeks)	Median 38 ng/mL IQR 72	Maternal age, race, education level, pre-pregnancy BMI	Phthalates' metabolites were inversely associated with BW. The maximum IQR was associated with a 0.14 decrease in the BW z-score (95% CI: −0:23, −0:04), which reaches 50 g at birth.
	[10]	LIFE Child study (Germany) 2011–2016	333 mother–infant pairs	Cohort	Pregnancy urine (3° trimester)	MG 20.45 (17.45–23.97) ng/mL	Child sex, gestational length, maternal age, pre-pregnancy BMI, parental's educational level, occupational status, household income, and smoking status	An 188 g decrease for each logarithmic unit increase of the metabolite ΣHMWP (β = −188.41, 95% CI = −365.41, - 11.41), **(in girls** p = 0.04).
	[17*]	Pregnant African American women (Atlanta–Georgia) 2014–2018.	426 participants	Cohort	Maternal blood (8–14 weeks)	Q2 0.45–0.71 ng/mL	Gestational week at delivery	Lowest BW was found in the Q2 of PFOA (β = −126 g [95% CI - 241–10])
PFAS	[18*]	South China 2017–2019	224 mother–newborn pairs	Cohort	Maternal blood – 3° trimester and cord blood	PFNA GM 0.51 (0.48–54)ng/mL	Maternal age, newborn sex, pre-pregnancy BMI, maternal education, parity, tobacco & alcohol exposure, gestational age.	Each unit increase in PFAS was significantly associated with a decrease in BW -123.57 g (95% CI: −214.41, −32.74)
Increased BW								
Manganese	[12]	Japan Environment & Children's Study (JECS) (2011–2014)	93,739 mother–infant pairs	Cohort	Blood's Pregnant women second or third trimester	Median 15.40 (2.84–60.80) ng/g	Maternal age, pre-pregnancy BMI, alcohol consumption and smoking status, income, education, gestational age, sex, parity	A two-fold increase in maternal Mn concentrations (2.84–60.80 ng/g) was associated with a 50.6 g (95% CI: 35.50–44.10) increase in BW
PCB	[19]	Upstate KIDS Study (New York State) 2008–2010	2065 infants	Cohort	Whole-blood's newborn	Mean (SD) 0.061 (0.050)	Maternal age	The risk of being born LGA was higher among newborns presenting concentrations greater than 0.1 ng/mL PCB (p = 0.02)

Table 3

Exposure to environmental pollutants and effects on childhood WG.

Agent	Ref	Study setting and year	Study sample size;	Study type	Biological sample	Exposure levels and metrics	Covariate adjustment	Results
Increased WG								
DDE	[25]	LIFE Child cohort. Germany 2011–2016	324 pregnant	Cohort	Maternal 24th weeks and babies (6 month/ 1 Year age) serum	Mean (SD) 558.73 ± 439.62 pg/ LmL	Maternal age, lipid concentration, pre-pregnancy BMI, cotinine	Weight gain in children up to two years of age born to women DDE exposed, (90th percentile was 6,9% more than 10th percentile)
DDT	[27]	Wuhan, China 2014–2015	1039 mother–infant pairs	Cohort	Maternal blood-16th Weeks	GM 0.005 (0.004–0.006) ng/ mL	Maternal age, pre-pregnancy BMI, weight at delivery, parity, pregnancy complications, gestational age.	Higher DDT concentrations in cord serum associated with higher BMI Z-score at 6 and 12 months of age [β = 0.03, 95% CI: 0.00, 0.06]
HCH	[27]	Wuhan, China 2014–2015	1039 mother–infant pairs	Cohort	Maternal blood-16th weeks	GM 0.28 (0.26–0.30) ng/mL	Maternal age, pre-pregnancy BMI, weight at delivery, parity, pregnancy complications, gestational age.	Higher β-HCH concentrations in cord serum associated with higher BMI Z-score at 12 months [β = 0.07, 95% CI: 0.01, 0.13] and 24 months [β = 0 0.08, 95% CI: 0.02, 0.14] of age
PFOA	[7]	Cincinnati, OH (2003–2006)	345 mother–child pairs	Cohort	Maternal serum-16 weeks-delivery	Median 17.3 (4.3–6.5) ng/mL	Maternal race, age, marital status, parity, pre-pregnancy BMI.	Children born to women with higher PFOA concentrations displayed an early childhood lower BMI and a higher BMI at age 12
PHTALATE	[28]	Wuhan, China 2014–2015	814 mother–offspring pairs	Cohort	Pregnant urine at 3 trimesters	Median 0.09 (0.06–0.40) ng/mL	Gestational age, physical parameters, socioeconomic characteristics, pre-pregnancy BMI, Parity, infant sex, breastfeeding, smoking, alcohol consumption, physical activities.	Pregnancy first trimester DEHP levels positively associated with BMI Z-scores at 24 months (β: 0.095, 95% CI: 0.022, 0.167)
	[29]	Ma'anshan Birth Cohort (MABC) 2013–2021. Anhui Province-China	990 mother–daughter pairs	Cohort	Pregnant urine at 3 trimesters	MEHHP 2.095 (1.014,4.328) DEHP 2.336 (1.022,5.338)	Maternal age, pre-pregnancy BMI, residence, parity, education, ethnicity, alcohol consumption, occupation, gestational weight gain, gestational diabetes, hypertension, delivery status.	MEHHP Prenatal exposure (OR = 2.095, 95% CI = 1.014–4.328) and DEHP (OR = 2.336, 95% CI = 1.022–5.338) associated with higher increased BMI chance up to 12 years of age (**in girls**)
	[30]	Spanish INMA	1015 participants	Cohort	First- and third-trimester maternal urine	Low to high (r = 0.16–0.83)	Maternal age, pre-pregnancy BMI, educational level, pregnancy-smoking.	The metabolite benzophenone-3 (BP3) non-monotonically associated with higher BMI Z-score

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Table 3. (***continued***)

Agent	Ref	Study setting and year	Study sample size;	Study type	Biological sample	Exposure levels and metrics	Covariate adjustment	Results
PBDE	[31]	Laizhou Wan Birth Cohort (LWBC) Shandong, China 2010–2012,	207 mother–child pairs	Cohort	Maternal serum at delivery	Median 20.61 (1.26, 309.86) ng/g lipid	Maternal age, maternal BMI, parity, gestational age, pregnancy weight gain, smoking status, child sex.	Positive associations in weight Z-scores with congeners BDE-153 (ÿ = 0.38, 95% CI: 0.11, 0.65), 7 PBDEs (ÿ = 0.35, 95% CI: 0.02, 0 0.67) **(in boys)**
Reduced WG								
CADMIUM	[22]	Guangdong, China 2018–2019,	349 women	Cohort	Maternal urine first and third trimesters	Median (ug/g creatinine) First trimester 1.16 (0.11–8.06) Third trimester 0.98 (0.24–4.38)	Maternal age, alcohol and smoking consumption and exposure, education and income level, parity, pre-pregnancy BMI.	First trimester pregnancy exposure associated with decreased infant weight at three and six months (–101 g/ug/gr and –97 g/ug/gr) urinary Cd, respectively (**in girls**)
	[23]	Matlab, Bangladesh 2002–2012	1530 mother–child dyads	Cohort	Maternal erythrocyte, children urine/10 years	Median 0.24 (0.083; 0.64) µg/L	Housing structure, dwelling characteristics and family ownership of assets, maternal weight, education, conception season.	Maternal erythrocyte Cd inversely associated with weight-for-age Z-scores during childhood (B: –0.071, 95% CI: –0.14,-0.0047) p = 0.036. **(in boys)**
LEAD	[23]	Matlab, Bangladesh 2002–2012	1530 mother-child dyads	Cohort	Maternal erythrocyte, children urine/10 years	Median 1.6 (0.65; 4.1) µg/L	Housing structure, dwelling characteristics and family ownership of assets, maternal weight, education, conception season.	Urinary Pb inversely associated with weight-forage Z-scores (B: –0.084; 95% CI: –0.16, –0.0085) p = 0.029 (**in boys**)
PYRETHROIDS	[32]	South Africa 2012–2013	751 children	Cohort	Peripartum maternal urine	GM (SD) 0.55 (3.07) µg/L	Mothers age, marital status, total household income, household size, food poverty	10-fold increase in maternal metabolite trans-3-concentrations (2,2,-dicolorvinyl)-2,2-dimethyl-cyclopropane carboxylic acid was associated with a 21 g reduction (95%CI = –40, –1.6) in Weight. (**in boys**)
PHTALATE	[28]	Wuhan, China 2014–2015	814 mother-offspring pairs	Cohort	Maternal urine/ three trimesters	Median 0.09 (0.06–0.40) nmol/mL	Gestational age, physical parameters, socioeconomic characteristics, pre-pregnancy BMI, Parity, infant sex, breastfeeding, smoking, alcohol consumption, physical activities	Second trimester DEHP levels negatively associated with BMI Z-scores at 6 months (β: –0.316, 95% CI: –0.542, –0.089) and 12 months (β: –0.296, 95% CI: - 0.584, –0.008) **(in girls)**

Conclusion

As weight is a predictor of child health, any factors that can potentially interfere with child weight, including environmental pollutants, should be a public health concern. Environmental pollutants can influence birth weight and child weight gain, however, it is necessary to consider intervening factors that also influence pregnant women and babies weight, such as sex, socioeconomic factors, age, smoking, maternal diseases, parity, maternal BMI, breastfeeding. Further studies taking into account the exposure periods (prenatal and postnatal) to environmental pollutants, sex differences and exposure to multiple pollutants are required to improve the knowledge about birth weight and weight gain in childhood.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

Data availability

No data was used for the research described in the article.

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References

Papers of particular interest, published within the period of review, have been highlighted as:

* of special interest

1. World Health Organization (WHO): *Global status report on non communicable diseases 2014*. Geneve. 2014. ISBN 978 92 4 156485 4 URL:, http://apps.who.int/iris/bitstream/10665/148114/1/9789241564854_eng.pdf?ua=1.

2. Rosenbaum PF, *et al.*: **Metabolic syndrome is associated with exposure to organochlorine pesticides in Anniston, AL, United States**. *Environ Int* 2017, **108**:11–21, https://doi.org/10.1016/j.envint.2017.07.017.

3. World Health Organization (WHO): *World health statistics 2022: monitoring health for the SDGs, sustainable development goals*. Geneve. 2022. ISBN 978-92-4-005114-0. URL:, https://www.who.int/publications/i/item/9789240051157.

4. World Health Organization (WHO): *Obesity and overweight*. 2021. Geneve, https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight.

5. Heindel JJ, Newbold R, Schug TT: **Endocrine disruptors and obesity**. *Nat Rev Endocrinol* 2015, **11**:653–661, https://doi.org/10.1038/nrendo.2015.163.

6. Vrijheid M, *et al.*: **Environmental pollutants and child health: a review of recent concerns**. *Int J Hyg Environ Health* 2016, **219**: 331–342, https://doi.org/10.1016/j.ijheh.2016.05.001.

7. * Braun JM, Eliot M, Papandonatos GD, Buckley JP, Cecil KM, Kalkwarf HJ, Chen A, Eaton CB, Kelsey K, Lanphear BP, Yolton K: **Gestational perfluoroalkyl substance exposure and body mass index trajectories over the first 12 years of life**. *Int J Obes* 2021, **45**:25–35, https://doi.org/10.1038/s41366-020-00717-x.

Higher β-HCH concentrations in cord serum associated with higher BMI Z-score at 12 months [β = 0.07, 95% CI: 0.01, 0.13] and 24 months [β = 0 0.08, 95% CI: 0.02, 0.14] of age.

8. Pearce JL, Neelon B, Bloom MS, Buckley JP, Ananth CV, Perera F, Vena J, Hunt K: **Program collaborators for Environmental influences on Child Health Outcomes.: exploring associations between prenatal exposure to multiple endocrine disruptors and birth weight with exposure continuum mapping**. *Environ Res* 2021, **200**, 111386, https://doi.org/10.1016/j.envres.2021.111386.

9. * Rahman ML, *et al.*: **Early pregnancy exposure to metal mixture and birth outcomes – a prospective study in Project Viva**. *Environ Int* 2021, **156**, 106714, https://doi.org/10.1016/j.envint.2021.106714.

Each IQR increase in As (1.1 ng/g) was associated with a 29.3 g (95% CI: −59.5, 1.0) decrease in BW. was stronger in males (p = 0.04). Each IQR increase (0.28 ng/g) was associated with a 26.6 g reduction (95% CI: −51.8, - 1.4) in BW; Each IQR increase (10.1 ng/g) was associated with a 33.9 g decrease (IC 95%: - 65.3, - 2.5 in BW.

10. * Nidens N, *et al.*: **Associations of prenatal exposure to phthalates and one phthalate substitute with anthropometric measures in early life: results from the German LIFE Child cohort study**. *Best Pract Res Clin Endocrinol Metabol* 2021, **35**, 101532, https://doi.org/10.1016/j.beem.2021.101532.

An 188 g decrease for each logarithmic unit increase of the metabolite ΣHMWP (β = −188.41, 95% CI = −365.41, - 11.41, Strong at females p = 0.04).

11. * Shih YH, Chen HY, Christensen K, Handler A, Turyk ME, Argos M: **Prenatal exposure to multiple metals and birth outcomes: an observational study within the National Children's Study cohort**. *Environ Int* 2021, **147**, 106373, https://doi.org/10.1016/j.envint.2020.106373.

Inverse association of maternal mercury exposure (Median: 0.58 μg/L 0,11–5,32) with birth weight in females p = 0,33.

12. * Takatani T, Eguchi A, Yamamoto M, Sakurai K, Takatani R, Taniguchi Y, Nakayama SF, Mori C: **Kamijima M.; Japan Environment and Children's Study Group.: individual and mixed metal maternal blood concentrations in relation to birth size: an analysis of the Japan Environment and Children's Study (JECS)**. *Environ Int* 2022, **165**, 107318, https://doi.org/10.1016/j.envint.2022.107318.

A two-fold increase in maternal Cd concentrations (0.10–5.33 ng/g) was associated with a 14.9 g (95% CI: 11.31–18.43) decrease in BW. A two increase in maternal Pb concentrations was associated with a 39.8 g (95% CI: 35.50–44.10) decrease in BW. A two-fold increase in maternal concentrations was associated to a 54.8 g decrease (95% CI: 41.52, 68.11) in BW.

13. * Choi S, Lee A, Choi G, Moon HB, Kim S, Choi K, Park J: **Free Cortisol Mediates associations of maternal urinary Heavy metals with neonatal anthropometric measures: a cross-sectional study**. *Toxics* 2022, **10**:167, https://doi.org/10.3390/toxics10040167.

The Ponderal index, was negatively associated with maternal urinary Pb (β = −0.23, 95% CI: −0.46–0.07). The Ponderal index, was negatively associated with Hg (β = −0.26, 95% CI: −0.44, −0.08)

14. * Hu JMY, Arbuckle TE, Janssen P, Lanphear BP, Zhuang LH, Braun JM, McCandless LC: **Prenatal exposure to endocrine disrupting chemical mixtures and infant birth weight: a Bayesian analysis using kernel machine regression**. *Environ Res* 2021, **195**, 110749, https://doi.org/10.1016/j.envres.2021.110749.

A two-fold increase in maternal Pb conncentrations reduced mean birth weight by −39 g (95% CI: −69, −9).

15. * Ferguson KK, *et al.*: **Prenatal phthalate exposure and child weight and adiposity from in Utero to 6 Years of age**. *Environ Health Perspect* 2022, **130**, 47006, https://doi.org/10.1289/EHP10077.

Phthalates' metabolites were inversely associated with BW. The maximum IQR was associated with a 0.14 decrease in the BW z-score (95% CI: −0:23, −0:04), which reaches 50 g at birth.

16. Yang Z, Liu HY, Yang QY, Chen X, Li W, Leng J, Tang NJ: **Associations between exposure to perfluoroalkyl substances and birth outcomes: a meta-analysis**. *Chemosphere* 2022, **291**, 132909, https://doi.org/10.1016/j.chemosphere.2021.132909.

17. * Chang CJ, *et al.*: **Per- and polyfluoroalkyl substance (PFAS) exposure, maternal metabolomic perturbation, and fetal growth in African American women: a meet-in-themiddle approach**. *Environ Int* 2022, **158**, 106964, https://doi.org/10.1016/j.envint.2021.106964.

Phtalates' Metabolites were inversely associated with BW. The maximum IQR was associated with a 0.14 decrease in the BW z-score (95% CI: –0:23, –0:04), which reaches 50 g at birth.

18. * Luo D, Wu W, Pan Y, Du B, Shen M, Zeng L: **Associations of prenatal exposure to per- and polyfluoroalkyl substances with the neonatal birth size and hormones in the growth hormone/insulin-like growth factor Axis**. *Environ Sci Technol* 2021, **55**:11859–11873, https://doi.org/10.1021/acs.est.1c02670.

Each unit increase in PFAS was significantly associated with a decrease in BW -123.57 g (95% CI: –214.41, –32.74).

19. * Bell GA, Perkins N, Buck Louis GM, Kannan K, Bell EM, Gao C, Yeung EH: **Exposure to persistent organic pollutants and birth Characteristics: the upstate KIDS study**. *Epidemiology* 2019, **30**(Suppl 2):S94–S100, https://doi.org/10.1097/EDE.0000000000001095.

The risk of being born LGA was higher among newborns presenting concentrations greater than 0.1 ng/mL PCB (p = 0.02)

22. * Liu L, *et al.*: **Maternal urinary cadmium concentrations in early pregnancy in relation to prenatal and postpartum size of offspring**. *J Trace Elem Med Biol* 2021, **68**, 126823, https://doi.org/10.1016/j.jtemb.2021.126823.

First trimester pregnancy exposure associated with decreased infant weight at three and six months (–101 g/ug/gr and –97 g/ug/gr) urinary Cd, respectively (in girls).

23. * Malin IA, Warnqvist A, Rahman SM, Ekström EC, Rahman A, Vahter M, Kippler M: **Environmental metal exposure and growth to 10 years of age in a longitudinal motherchild cohort in rural Bangladesh**. *Environ Int* 2021, **156**, 106738, https://doi.org/10.1016/j.envint.2021.106738.

Maternal erythrocyte Cd inversely associated with weight-for-age Z-scores during childhood (B: –0.071, 95% CI: –0.14,-0.0047) p = 0.036. (in boys). Urinary Pb inversely associated with weight-forage Z-scores (B: –0.084; 95% CI: –0.16, –0.0085) p = 0.029 (in boys).

24. Rosofsky AS, Fabiano MP, Ettinger de Cuba S, Sandel M, Coleman S, Levy JI, Coull BA, Hart JE, Zanobetti A: **Prenatal exposure to environmental particles and longitudinal trajectories of weight gain in early childhood**. *Int J Environ Res Publ Health* 2020, **17**:1444, https://doi.org/10.3390/ijerph17041444.

25. * Krönke AA, *et al.*: **Persistent organic pollutants in pregnant women potentially affect child development and thyroid hormone status**. *Pediatr Res* 2022, **91**:690–698, https://doi.org/10.1038/s41390-021-01488-5.

Weight gain in children up to two years of age born to women DDE exposed, (90th percentile was 6,9% more than 10th percentil).

26. Stratakis N, Rock S, La Merrill MA, Saez M, Robinson O, Fecht D, Vrijheid M, Valvi D, Conti DV, McConnell R, Chatzi VL: **Prenatal exposure to persistent organic pollutants and childhood obesity: a systematic review and meta-analysis of human studies**. *Obes Rev* 2022, **23**(Suppl 1), e13383, https://doi.org/10.1111/obr.13383. Suppl 1.

27. * Yang C, Fang J, Sun X, Zhang W, Li J, Chen X, Yu L, Xia W, Xu S, Cai Z, Li Y: **Prenatal exposure to organochlorine pesticides and infant growth: a longitudinal study**. *Environ Int* 2021, **148**, 106374, https://doi.org/10.1016/j.envint.2020.106374.

Higher DDT concentrations in cord serum associated with higher BMI Z-score at 6 and 12 months of age [β = 0.03, 95% CI: 0.00, 0.06]. Higher β-HCH concentrations in cord serum associated with higher BMI Z-score at 12 months [β = 0.07, 95% CI: 0.01, 0.13] and 24 months [β = 0 0.08, 95% CI: 0.02, 0.14] of age.

28. * Li J, Qian X, Zhou Y, Li Y, Xu S, Xia W, Cai Z: **Trimester-specific and sex-specific effects of prenatal exposure to di(2-ethylhexyl) phthalate on fetal growth, birth size, and early-childhood growth: a longitudinal prospective cohort study**. *Sci Total Environ* 2021, **777**, 146146, https://doi.org/10.1016/j.scitotenv.2021.146146.

Pregnancy first trimester DEHP levels positively associated with BMI Z-scores at 24 months (β: 0.095, 95% CI: 0.022, 0.167). Second trimester DEHP levels negatively associated with BMI Z-scores at 6 months (β: –0.316, 95% CI: –0.542, –0.089) and 12 months (β: –0.296, 95% CI: - 0.584, –0.008) (In girls).

29. * Gao H, Geng ML, Gan H, Huang K, Zhang C, Zhu BB, Sun L, Wu X, Zhu P, Tao FB: **Ma'anshan Birth Cohort.: prenatal single and combined exposure to phthalates associated with girls' BMI trajectory in the first six years**. *Ecotoxicol Environ Saf* 2022, **241**, 113837, https://doi.org/10.1016/j.ecoenv.2022.113837.

MEHHP Prenatal exposure (OR = 2.095, 95% CI = 1.014–4.328) and DEHP (OR = 2.336, 95% CI = 1.022–5.338) associated with higher increased BMI chance up to 12 years of age (in girls).

30. * Güil-Oumrait N, *et al.*: **Prenatal exposure to mixtures of phthalates and phenols and body mass index and blood pressure in Spanish preadolescents**. *Environ Int* 2022, **169**, 107527, https://doi.org/10.1016/j.envint.2022.107527.

The metabolite benzophenone-3 (BP3) nonmonotonically associated with higher BMI Z-score.

31. * Hu Y, Lu Q, Huang C, Gao Y, Tian Y, Fan L, Liu S: **Associations between prenatal exposure to polybrominated diphenyl ethers and physical growth in a seven year cohort study**. *Chemosphere* 2022, **303**, 135049, https://doi.org/10.1016/j.chemosphere.2022.135049.

Positive associations in weight Z-scores with congeners BDE-153 (ÿ = 0.38, 95% CI: 0.11, 0.65), 7 PBDEs (ÿ = 0.35, 95% CI: 0.02, 0 0.67) (among boys).

32. * Kim J, Yang S, Moodie EEM, Obida M, Bornman R, Eskenazi B, Chevrier J: **Prenatal exposure to insecticides and weight trajectories among South African children in the VHEMBE birth cohort**. *Epidemiology* 2022, **33**:505–513, https://doi.org/10.1097/EDE.0000000000001487.

10-fold increase in maternal metabolite trans-3- concentrations (2,2,-dicolorvinyl)-2,2-dimethyl-cyclopropane carboxylic acid was associated with a 21 g reduction (95%CI = –40, –1.6) in Weight. (In boys).

33. Heidari S, Babor TF, De Castro P, *et al.*: **Sex and Gender Equity in Research: rationale for the SAGER guidelines and recommended use**. *Res Integr Peer Rev* 2016, **1**:2, https://doi.org/10.1186/s41073-016-0007-6.

34. United Nations Children's Fund (UNICEF), World Health Organization: *UNICEF-WHO: low birthweight estimates: levels and trends 2000–2015*. Geneva: World Health Organization; 2019. Licence: CC BY-NC-SA 3.0 IGO.

35. World Health Organization (WHO),United Nations Children's Fund (UNICEF), World Bank Group: *Nurturing care for early childhood development: a framework for helping children survive and thrive to transform health and human potential*. Geneva: World Health Organization; 2018. Licence: CC BY-NC-SA 3.0 IGO.

36. Bianchi ME, Restrepo JM: **Low birthweight as a risk factor for non-communicable diseases in adults**. *Front Med* 2022, **8**, 793990, https://doi.org/10.3389/fmed.2021.793990. PMID: 35071274; PMCID: PMC8770864.

37. Prüss-Ustün A, Wolf J, Corvalán C, Bos R, Neira M: *Prevenjng disease through healthy environments: a global assessment of the burden of disease from environmental risks. Updated 2016 data tables*. Geneva: World Health Organizajon; 2019. hmps://www.who.int/publicajons/i/item/9789241565196.