REVIEW PAPER

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RELATIONSHIP BETWEEN PRENATAL AND POSTNATAL EXPOSURE TO BPA AND ITS ANALOGUES (BPS, BPF) AND ALLERGIC DISEASES

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Abstract

Bisphenols, endocrine disrupting chemicals, are widely used in daily life. Continued exposure during key developmental periods of life (pregnancy, infancy and early childhood) can contribute to adverse health consequences such as decreased lung function, wheezing/asthma, the occurrence of allergies or changes in immune system responses. The purpose of this review is to present the current state of knowledge on the effects of prenatal or postnatal exposure to bisphenol A (BPA), bisphenol S (BPS) and bisphenol F (BPF) on the development of allergic diseases in childhood. A comprehensive and systematic search of PubMed, Scopus and Web of Science databases was conducted. The review is restricted to studies published since 2015, in English in peer-reviewed journals. Based on keywords, 2648 studies were identified and reviewed for eligibility. Finally, 8 epidemiological studies were found to be appropriate for inclusion in this publication. The data collected in this review suggests that there is an association between maternal exposure during pregnancy or childhood to BPA and the development of allergic diseases. Most studies reported positive relationships between BPA exposure and at least one of the types of allergic disease. The paucity of studies and the observed differences in findings regarding the association between prenatal/postnatal exposure to BPS and/or BPF do not allow firm conclusions to be drawn. Further research is needed to identify the vulnerable population and the mechanisms responsible for the development of undesirable health consequences. Int J Occup Med Environ Health. 2023;36(5):575–86

Key words:

allergic diseases, bisphenols, prenatal and postnatal exposure, wheezing, asthma, atopic dermatitis

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INTRODUCTION

The increasing incidence of allergic diseases is a serious public health problem. Exposure to environmental pollutants during prenatal and early life can increase the risk of developing respiratory diseases and allergies in later life [1–5]. Bisphenols, endocrine disrupting chemicals (EDCs), are widely used in the production of plastics, thermal paper and epoxy resins and exposure of the general population can be through oral, dermal or inhalation routes [6]. Bisphenol A (BPA) is the most common representative of the bisphenol family. It can cross the blood-placental barrier and its presence has been detected in amniotic fluid or breast milk, suggesting that exposure may extend to both pregnancy and early childhood [7]. Continued exposure during key developmental periods of life (pregnancy, infancy and early childhood) may contribute to adverse health outcomes such as decreased lung function [8,9], wheezing and/or asthma [10,11], the occurrence of allergies [12] or changes in immune system responses [13,14]. Bisphenol A has been listed by the European Chemicals Agency (ECHA) in the Candidate List of "substances of very high concern" which has led to a reduction in its production and the consequent emergence of substitutes including bisphenol F (BPF) and bisphenol S (BPS) [15]. As indicated by research findings, both BPS and BPF are hormonally active and can disrupt endocrine balance [16,17].

The available evidence on the effect of prenatal or postnatal exposure to BPA on the occurrence of allergic diseases in childhood has been summarized in several systematic reviews [18–21]. Robinson et al. [18], based on data from studies published up to 2015, note the lack of consistent conclusions regarding the role of BPA in the occurrence of allergy and asthma in children. Also, the results collected in a systematic review of the literature covering papers published up to 2016 are contradictory and inconclusive because 3 studies found prenatal exposure to BPA to be associated with an increased risk of wheezing/asthma in childhood, while 1 found a reduced risk of wheezing [19]. Wu et al. [20], based on a systematic review and meta-analysis, found that the risk of childhood asthma is increased by prenatal or postnatal exposure to BPA. Tang et al. [21], based on the results of a meta-analysis, pointed out that there was a positive association between exposure to BPA during pregnancy and the occurrence of allergic diseases in childhood.

Methodological issues including the design of the study, the different period and level of exposure, not sufficient control for confounding variables, the age of the child and the methods used to assess allergic symptoms may be the reason for the differences observed in the results of previous studies.

On the other hand, none of the reviews presented here included studies evaluating the association between prenatal and/or postnatal exposure to BPS and/or BPF and the occurrence of allergic diseases in childhood.

The purpose of this review is to present the current state of knowledge on the effects of prenatal or postnatal exposure to BPA and its 2 main analogs BPS and BPF on the development of allergic diseases in childhood.

METHODS

This summary was prepared in accordance with the components of The Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 (PRISMA 2020) [22].

Eligibility criteria

Inclusion criteria for the review were defined as follows:

1) study performed in humans;
2) published since 2015, in English in peer-reviewed journals;
3) the concentration of bisphenols (BPA and/or BPS and/or BPF) was determined in urine samples collected from the mother at least once during pregnancy or from children;
4) the relationship between prenatal and/or postnatal exposure to selected bisphenols (BPA and/or BPS

and/or BPF) and the occurrence of allergic diseases in children was assessed;

5) the occurrence of the following health effects in children was assessed:
   a) asthma,
   b) wheezing,
   c) eczema/atopic dermatitis,
   d) aeroallergies,
   e) allergic rhinitis;
6) results were given as odds ratio (OR), relative risk (RR) or hazard ratio (HR) with the corresponding 95% confidence intervals (95% CIs).

Articles without full text, meta-analyses, or reviews were not eligible for review.

Information sources search strategy

A comprehensive and systematic search of PubMed, Scopus and Web of Science databases was conducted to identify studies that analyzed the association between prenatal and/or postnatal exposure to BPA and/or 2 of its analogs BPS and BPF and the incidence of allergic diseases in children. The search was conducted in October–December 2022 based on keywords used in various combinations: bisphenols exposure, bisphenol A or BPA child exposure, bisphenol S or BPS child exposure, bisphenol F or BPF child exposure, allergic diseases, childhood wheezing/asthma, lung function, childhood eczema/atopic dermatitis.

Selection process and data collection process

Two independent reviewers conducted a literature search and review, taking into account the inclusion criteria. In the first step, non-relevant references were removed on the basis of the title and abstract due to ineligibility. The second stage was to review the full text, and the resulting doubts and inconsistencies were dispelled and eliminated through discussion.

In the selection process, reviewers from all publications identified the following key information: first author name, publication year, study design and population characteristics (study name, country, study period, sample size, children's age), maternal or children exposure period, urinary BPA and/or BPS and/or BPF concentrations, respiratory outcome, the methods used to diagnose allergic disease, confounding factors and the results of analysis.

RESULTS

Study selection

Based on keywords, 2648 studies were identified and reviewed for eligibility. Initially, after reviewing the abstract and title, 805 irrelevant studies, 462 duplicates and 28 reviews were excluded. The main reasons for exclusion were: animal studies, concentrations of test bisphenols determined in biological material other than urine, lack of data on exposure to BPA and/or BPS and/or BPF. Forty-eight full-text articles remained, of which 8 epidemiological studies were found to be appropriate for inclusion in this publication. The detailed description selection process for studies included in the review is shown in Figure 1.

Characteristics of studies

Seven of the included studies were cohort studies, 1 study was a cross-sectional survey and all of them analyzed the association between prenatal/postnatal exposure to BPA and/or BPS and/or BPF and the incidence of allergic diseases in children (Table 1). All studies included in the review were published between 2015 and 2021. The studies were carried out in 4 countries, 1 in Spain, 1 in France, 3 in China and 3 in the United States. According to the established criteria, collected urine samples were used to assess exposure to selected bisphenols.

In 6 out of 8 studies, included in the review the concentration of bisphenols was measured in maternal urine collected during pregnancy (in 4 studies the urine was collected during the third trimester of pregnancy and in 2 it was collected twice during the first and the second

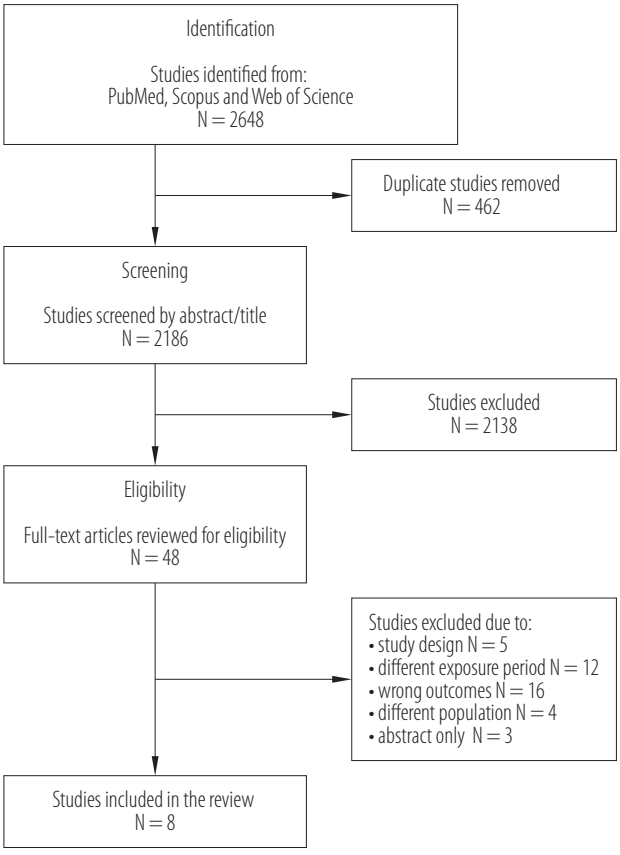

Figure 1. The detailed description of selection process for studies on the effects of prenatal or postnatal exposure to bisphenol A (BPA), bisphenol S (BPS) and bisphenol F (BPF) on the development of allergic diseases in childhood, published in 2015–2021

trimester of pregnancy). In 2 studies it was measured in urine collected from children aged ≥3–12 years.

Only in 2 studies, concentrations of BPA and its main analogs (BPS, BPF) were determined, in the remaining studies, only BPA concentrations were determined. The size of the study population ranged 111–3538 participants. Table 2 shows concentrations of BPA, BPS and BPF in maternal/child urine collected during pregnancy/childhood. In most studies (N = 7), allergic diseases in children were diagnosed on the basis of the International Study of Asthma and Allergies in Children (ISAAC) recommendations [23]. In the study by Mendy et al. the other questionnaire completed by parents was used [24]. In all of the above studies the adjustment for potential confounders was performed. The following covariates were among the most frequently evaluated: maternal age, maternal education, maternal active or passive smoking during pregnancy, parental positive history of allergy. Maternal education level was included in all studies while maternal smoking or exposure to tobacco smoke during pregnancy was included in most studies (Table 3).

Bisphenols

Childhood wheezing and asthma

Table 4 shows the results of studies analyzing the association between prenatal or postnatal exposure to selected bisphenols and the occurrence of wheezing and asthma in children. Three studies evaluated the association between prenatal exposure to BPA and childhood wheezing [11,25,26]. Only in an analysis by Gascon et al. [11] it was observed that prenatal exposure to BPA may increase the risk of wheezing in offspring (relative risk (RR) 1.20 [1.03, 1.40; p = 0.02]). The impact of prenatal BPA exposure on the occurrence of asthma symptoms in childhood was analyzed in 4 studies [11,12,25,26]. However, only Buckley et al. [26] indicated that prenatal exposure to BPA may increase the risk of asthma symptoms in 6–7 year old boys (odds ratio (OR) 1.66 [1.04, 2.66; p = 0.03]). Wang et al [27], and Mendy et al. [24] evaluated the association between postnatal urinary BPA concentrations and measures of asthma morbidity. Evidence from a study by Wang et al. [27] suggests that childhood exposure to BPA may increase the risk of asthma in 3- and 6-year-olds (OR 1.29 [1.08, 1.55; p ≤ 0.05], OR 1.27 [1.04, 1.55; p ≤ 0.05] asthma at 3 and 6 years of age and BPAG level at 3 years of age, respectively), (OR 1.50 [1.06, 2.11; p ≤ 0.05] asthma at 6 years of age and BPAG level at 6 years of age) [27]. Only Mendy et al. [24] additionally examined the relationship between BPF and BPS concentrations in children's urine samples and the occurrence of asthma. Results suggested that exposure to BPF was positively associated with current asthma (OR 1.54 [1.16, 2.04; p = 0.003]).

Table 1. Characteristics of studies (published in 2015–2021) included in the systematic review on the effects of prenatal or postnatal exposure to bisphenol A (BPA), bisphenol S (BPS) and bisphenol F (BPF) on the development of allergic diseases in childhood

Reference	Study	Location	Enrolling period	Sample size [n]	Exposure assessment	Allergic disease assessment	Symptoms	Children's age at allergic diseases assessment
Prenatal exposure								
Gascon et al., 2015 [11]	INMA: INfancia y Medio Ambiente (cohort)	Catalonia (Spain)	2004–2006	654	maternal 2 urine samples (12 and 32 wk gest) BPA	ISAAC, IgE	chest infections, bronchitis, wheezing, asthma, eczema	from birth until 7 years of age
Vernet et al., 2017 [25]	EDEN: Etude des Déterminants pré et post natals du développement et de la santé de l'Enfant (cohort)	Nancy, Poitiers (France)	2003–2006	587	single urine sample (23–29 wk gest) BPA	ISAAC	bronchiolitis/ bronchitis, wheezing, asthma	from 8 months until 5 years of age (only boys)
Zhou et al., 2017 [29]	Prenatal cohort in Wuhan, China (cohort)	Wuhan (China)	2012–2014	412	maternal, single urine sample (3 days before delivery) BPA	ISAAC	wheezing, itchy rash, eczema	6 months after birth
Buckley et al., 2018 [26]	The Mount Sinai Children's Environmental Health Study (cohort)	New York (USA)	1998–2002	404	single urine sample (3rd trimester of pregnancy) BPA	ISAAC	wheezing, asthma, atopy	6 and 7 years of age
Berger et al., 2019 [12]	CHAMACOS: Center for the Health Assessment of Mothers and Children of Salinas (cohort)	California (USA)	1999–2000	601	maternal 2 urine samples (13 and 26 wk gest) BPA	ISAAC, Th1/Th2 cells	asthma, eczema, aeroallergies	7 years
Li et al., 2021 [28]	SMCHS: Shenyang Maternal and Child Health Study (cohort)	Shenyang (China)	2019–2020	111	within 2 days before delivery, BPA, BPS, BPF	ISAAC	eczema	at 6 and 12 months
Postnatal exposure								
Wang et al., 2016 [27]	CEAS: Childhood Environment and Allergic Diseases Study (cohort)	Taiwan (China)	2010	453	children 2 urine samples (3 and 6 years) BPA glucoronide (BPAG)	ISAAC, IgE	asthma, allergic rhinitis, atopic dermatitis	3 and 6 years
Mendy et al., 2020 [24]	NHANES: National Health and Nutrition Examination Survey (cross-sectional survey)	USA	2013–2016	3538	children and adults' urine (12 years or older) BPA, BPS, BPF	questionnaires	asthma, hay fever	12 years or older

ISAAC – International Study of Asthma and Allergies in Children.
Th1 – T helper 1; Th2 – T helper 2, wk gest – gestational weeks.

Table 2. Concentrations of the bisphenol A (BPA), bisphenol S (BPS) and bisphenol F (BPF) in maternal urine in studies published in 2015–2021

Reference	Exposure timing during pregnancy	Bisphenol				
		BPA	BPAG	SG-BPA*	BPS	BPF
Gascon et al., 2015 [11]	12 and 32 wk gest	Me 2.4 µg/g creatinine[#]				
Vernet et al., 2017 [25]	23–29 wk gest	Me 2.6 µg/l				
Zhou et al., 2017 [29]	3 days before delivery	GM 4.71 µg/g creatinine				
Buckley et al., 2018 [26]	3rd trimester of pregnancy	Me 1.3 µg/l				
Berger et al., 2019 [12]	13 and 26 wk gest	GM 1.5 µg/ml[#] Me 1.3 µg/ml				
Li et al., 2021 [28]	3rd trimester of pregnancy (within 2 days before delivery)	Me 10.05 µg/g creatinine		Me 7.46 ng/ml	n.a.	Me 0.63 µg/g creatinine
Mendy et al., 2020 [24]	children and adults' urine	GM (SE) 1.16 (0.04) µg/g creatinine			GM (SE) 0.44 (0.02) µg/g creatinine	GM (SE) 0.46 (0.02) µg/g creatinine
Wang et al., 2016 [27]	2 urine samples (3 and 6 years)		3 years – GM±GSD: 11.84±3.35 ng/ml 6 years – GM±GSD: 8.84±2.57 ng/ml			

n.a. – not available.
BPAG – BPA glucuronide; SG-BPA* – urinary specific gravity adjusted BPA (ng/ml).
GM – geometric mean; GSD – geometric standard deviation; wk gest – gestational weeks.
[#] Average of 2 measurements.

Table 3. Confounders adjusted for model's study in studies on the effects of prenatal or postnatal exposure to bisphenol A (BPA), bisphenol S (BPS) and bisphenol F (BPF) on the development of allergic diseases in childhood published in 2015–2021

Reference	Confounding factor
Gascon et al., 2015 [11]	maternal education, number of siblings and maternal smoking during pregnancy
Vernet et al., 2017 [25]	center, residence area, parental history of asthma or allergies, maternal ethnicity, maximal parental education level, maternal or passive smoking during pregnancy, postnatal passive smoking, older siblings, and child care. $FEV_{1\%}$ - additionally adjusted for child's height and age
Zhou et al., 2017 [29]	mother's age at delivery, level of education, BMI, passive smoking, and vitamin D supplementation during pregnancy, mode of delivery, gestational weeks, infant's gender, body weight at follow-up, and feeding characteristics
Buckley et al., 2018 [26]	creatinine, maternal age, race/ethnicity, pre-pregnancy body mass index, education, marital status, type of home ownership, smoking during pregnancy, person in household with asthma, person in household with allergies, number of occupants in the home, pets in the home, age at follow-up, and, for overall models, child's sex
Berger et al., 2019 [12]	maternal age, parity, household income as a proportion of poverty at baseline, child's family history of asthma, maternal education, mono(3-carboxypropyl) phthalate, bisphenol A, monocarboxyisooctyl phthalate
Wang et al., 2016 [27]	urine creatinine, maternal age, maternal education, maternal history of atopy, breast feeding, and ETS exposure
Mendy et al., 2020 [24]	age, sex, race/ethnicity, PIR, exposure to cigarette smoke, BMI, education level of the household reference person, family history of asthma, log10-transformed urinary creatinine, and glomerular filtration rate, as well as mutually adjusted for bisphenols
Li et al., 2021 [28]	maternal age, infant sex, cesarean, maternal education, exposure to cigarette smoking during pregnancy, parental positive history of allergy, pet keeping during pregnancy, complications of pregnancy, gestational age and feeding patterns within 4 months

Table 4. Associations between prenatal/postnatal bisphenols levels and wheezing or/and asthma, eczema/atopic dermatitis, and aeroallergies, allergic rhinitis in children in studies published in 2015–2021

Bisphenol	Reference	Respiratory outcome and effect
Wheezing or/and asthma		
prenatal exposure		
BPA	Vernet et al., 2017 [25]	wheezing (until age 5 years): HR 0.97 (0.82–1.15), p = 0.80
	Gascon et al., 2015 [11]	wheezing (birth until age 7 years): RR 1.20 (1.03–1.40), p = **0.02**
	Buckley et al., 2018 [26]	wheezing (6 or 7 years): OR 1.31 (0.89–1.93), p = 0.20
	Vernet et al., 2017 [25]	asthma (until age 5 years): HR 1.23 (0.97–1.55), p = 0.09
	Berger et al., 2019 [12]	asthma (at age 7 years): OR 1.03 (0.68–1.55)
	Gascon et al., 2015 [11]	asthma (at age 7 years): RR 1.21 (0.94–1.57), p = 0.14
	Buckley et al., 2018 [26]	asthma (6 or 7 years): OR 1.66 (1.04–2.66), p = **0.03**
postnatal exposure		
BPA	Wang et al., 2016[a] [27]	asthma (at age 3 years): OR 1.29 (1.08–1.55), p < **0.05** asthma (at age 6 years): OR 1.27 (1.04–1.55), p < **0.05**
	Wang et al., 2016[b] [27]	asthma (at age 6 years): OR 1.50 (1.06–2.11), p < **0.05**
	Mendy et al., 2020 [24]	current asthma: OR 0.89 (0.63–1.25), p = 0.50 asthma attacks in past 12 months: OR 0.85 (0.47–1.52), p = 0.58
BPS	Mendy et al., 2020 [24]	current asthma: OR 1.07 (0.79–1.45), p = 0.65 asthma attacks in past 12 months: OR 0.84 (0.52–1.36), p = 0.48
BPF	Mendy et al., 2020 [24]	current asthma: OR 1.54 (1.16–2.04), p = **0.003** asthma attacks in past 12 months: OR 1.41 (0.97–2.06), p = 0.07
Eczema/atopic dermatitis		
prenatal exposure		
BPA	Gascon et al., 2015 [11]	eczema (birth until age 7 years): RR 1.00 (0.85–1.18), p = 0.99 atopy (at age 4 years): RR 1.07 (0.65–1.77), p = 0.78
	Berger et al., 2019 [12]	eczema (at age 7 years): OR 1.00 (0.61–1.63)
	Buckley et al., 2018 [26]	eczema (6 or 7 years): OR 1.18 (0.83–1.67), p = 0.70
Cr-BPA	Li et al., 2021 [28]	eczema: OR 1.97 (0.79–4.95), p = 0.15
SG-BPA	Li et al., 2021 [28]	eczema: OR 2.73 (1.06–7.01), p = **0.04**
BPS	Li et al., 2021 [28]	eczema: OR 1.04 (0.42–2.56), p = 0.94
BPF	Li et al., 2021 [28]	eczema: OR 0.78 (0.31–1.99), p = 0.61
postnatal exposure		
BPA	Wang et al., 2016[a] [27]	atopic dermatitis – at age 3 years: OR 1.16 (0.92–1.45) – at age 6 years: OR 1.19 (0.95–1.49)
	Wang et al., 2016[b] [27]	atopic dermatitis (at age 6 years): OR 1.18 (0.83–1.68)
Aeroallergies, allergic rhinitis		
prenatal exposure		
BPA	Berger et al., 2019 [12]	aeroallergies (at age 7 years): OR 1.19 (0.91–1.57)

Table 4. Associations between prenatal/postnatal bisphenols levels and wheezing or/and asthma, eczema/atopic dermatitis, and aeroallergies, allergic rhinitis in children in studies published in 2015–2021 – cont.

Bisphenol	Reference	Respiratory outcome and effect
Aeroallergies, allergic rhinitis – cont.		
postnatal exposure		
BPA	Wang et al., 2016[a] [27]	allergic rhinitis – at age 3 years: OR 1.05 (0.88–1.26) – at age 6 years: OR 1.11 (0.92–1.35)
	Wang et al., 2016[b] [27]	allergic rhinitis (at age 6 years): OR 1.26 (0.78–2.04)
	Mendy et al., 2020 [24]	allergic rhinitis: OR 0.97 (0.43–2.18), p = 0.93
BPS	Mendy et al., 2020 [24]	allergic rhinitis: OR 0.98 (0.64–1.50), p = 0.92
BPF	Mendy et al., 2020 [24]	allergic rhinitis: OR 1.66 (1.12–2.46), p = **0.01**
Allergic diseases		
prenatal exposure		
BPA	Zhou et al., 2017 [29]	allergic diseases: OR 1.21 (1.02–1.47), p = **0.04**

BPA – bisphenol A; BPF – bisphenol F; BPS – bisphenol S; Cr-BPA – creatinine adjusted BPA; SG-BPA – urinary specific gravity adjusted BPA.
HR – hazard rate; OR – odds ratio; RR – relative risk.
Bolded are $p < 0.05$.
Association of allergic diseases at age [a] 3 and 6 years and urine BPAG levels (ng/ml) at 3 years, [b] 6 years and urine BPAG levels (ng/ml) at 6 years.

Childhood eczema and atopic dermatitis

Table 4 shows the results of studies analyzing the association between prenatal or postnatal exposure to selected bisphenols and the occurrence of eczema and atopic dermatitis. A total of 5 studies evaluated the association between BPA exposure and the risk of eczema/atopic dermatitis in children (in 4 studies prenatal exposure and in 1 study postnatal exposure were considered) [11,12,26–28]. Only Li et al. [28] noted that higher levels of BPA exposure during pregnancy increased the risk of developing infantile eczema (OR 2.73 [1.06, 7.01; p = 0.04]). In analyses focusing on BPS and BPF exposure, the result was not statistically significant.

Childhood aeroallergies/allergic rhinitis

Table 4 shows the results of studies analyzing the association between prenatal or postnatal exposure to selected bisphenols and the occurrence of aeroallergies/allergic rhinitis in children [12,24,27]. Only 1 study focused on the association between prenatal exposure to BPA and the incidence of aeroallergies – the result was not statistically significant [12]. According to Mendy et al. [24] higher concentration of postnatal exposure to BPF was positively associated with allergic rhinitis, (OR 1.66 [1.12, 2.46; p = 0.01]) [24].

Allergic diseases (including eczema and wheezing)

Based on the results, Zhou et al. [29] highlighted that prenatal exposure to BPA may contribute to the increased risk of allergic diseases in early childhood in girls. The study focused on 2 types of allergic diseases in childhood: eczema and wheezing (Table 4) [29].

Interpretation of the results

The data collected in this review suggest that there is an association between maternal exposure during pregnancy or childhood to BPA and the development of allergic diseases. Most studies reported positive relationships between BPA exposure and at least 1 of the types of allergic diseases, the exception being the study by Vernet et al. [25]. However, the authors highlight an observed

trend towards an increased risk of asthma in 5-year-old boys as a result of prenatal BPA exposure [25]. Only 2 studies have evaluated the effects of BPS and BPF on the development of allergies in children (1 study prenatal exposure, the other postnatal) including various types of allergic diseases [24,28]. Li et al. [28] suggested no association between maternal exposure during pregnancy to BPS or BPF and the occurrence of infantile eczema. On the other hand, the results of a study by Mendy et al. [24] indicated that exposure of children aged 12 years and older to BPS and BPF may be associated with a higher risk of asthma and/or hay fever. Conclusions based on such a small amount of data are very conservative.

The authors' results on BPA exposure are consistent with those published in earlier reviews and included in meta-analyses [19–21,30]. Tang et al. [21] concluded on the basis of their meta-analysis that prenatal exposure to BPA may be responsible for the development of allergic diseases in childhood. Wu et al. [20] emphasized that both prenatal and postnatal exposure to BPA can increase the risk of asthma symptoms. At the same time, the results of a meta-analysis suggest that BPA exposure in early pregnancy (up to 16 weeks) and postnatally may contribute to wheezing [20]. Data from a random-effects meta-analysis on individual participant data from 8 European birth cohorts suggest a positive association between maternal exposure during pregnancy to BPA and the occurrence of asthma and wheezing among school-aged girls [30].

The potential mechanisms linking the occurrence of allergic diseases to BPA exposure are not fully understood. It has been established that maternal exposure to environmental contaminants can impair the development of the immune system through disruption of epigenetics [31]. The ability of BPA to cross the placental barrier may explain the formation of genetic and epigenetic changes such as disruption of cellular functions and trophoblast invasiveness [32,33]. Bisphenol A may have a modulatory effect on the immune system. These effects have been observed in rodent and human studies and may include: increased production of pro-inflammatory cytokines and serum IgE immunoglobulins, increased eosinophilic airway inflammation, Th1/Th2 shift and also changes in Th17 abundance [34–36]. Studies are available indicating an association between BPA exposure and the occurrence of oxidative stress, which is suspected to be related to the development of asthma [37–39]. It is worth noting that BPA, as an allergen, may directly contribute to the development of allergies [18]. In addition, BPA is estrogenic and has an affinity for estrogen receptors, which may explain the suggested links between estrogen activity and asthma [40–43].

Strengths and limitations

This review is based on the most recent available studies on the association between prenatal/postnatal exposure to selected bisphenols and the occurrence of allergic diseases in children. To minimize subjective assessment, full-text reviews were carried out by 2 independent reviewers. The majority of the studies included in the review were cohort studies, which may provide evidence of causality between exposure and outcomes.

A limitation of the study may be the small number of studies that met the review's inclusion criteria. In addition, most studies based their exposure assessment on a single urine collection, which may not be sufficient to fully assess exposure given the short half-life. In addition, urine samples were collected from women of different gestational ages (2 studies – first trimester, 2 studies – second trimester, 4 studies – third trimester) and from children of different ages. The assessment of the association between prenatal/postnatal exposure to BPA and/or BPS and/or BPF and the occurrence of allergic diseases in children also included an age-differentiated group. Moreover, the outcomes assessments may constitute the limitation of the studies. The small number of studies analyzing the association between prenatal/postnatal exposure to BPS and/or BPF did not allow any firm conclusions to be drawn.

CONCLUSIONS

Exposure to environmental factors, individual genetic susceptibility, and their interactions contribute to the increased incidence of allergic diseases. Further research is needed to identify the vulnerable population and the mechanisms responsible for the development of undesirable health consequences.

Author contributions

Research concept: Monika Weteska, Kinga Polańska, Joanna Jerzyńska Agnieszka Jankowska

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