



Review

Toddler exposure to flame retardant chemicals: Magnitude, health concern and potential risk- or protective factors of exposure: Observational studies summarized in a systematic review



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HIGHLIGHTS

- Literature on toddler exposure (8–24 months) was systematically reviewed.
- 10 papers were found that measure flame retardants in or on toddlers.
- Only one study assessed health effects (found thyroid hormone disruption).
- To extent the amount of evidence, non-invasive sampling techniques are recommended.

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ABSTRACT

Endocrine disrupting flame retardant (FR) chemicals form a human health concern, that is investigated mostly from the perspective of adult- and early life exposure. No overview of studies on toddler exposure and health effects exist. However, toddlerhood is a critical developmental period and toddlers are at increased risk for exposure because of their age-specific behavior. This systematic review encompasses toddler FR exposure studies in three countries, associated health effects and potential environmental, demographic, or behavioral risk- or protective factors for toddler exposure. A systematic literature search in four databases (PubMed, Embase.com, The Cochrane Library (via Wiley) and Web of Science Core collection) resulted in the identification of ten publications representing seven unique studies that measured brominated and/or phosphorylated FRs in toddlers' (8–24 month-old) serum, urine, hand wipes and feces. This review showed that toddlers are exposed to a range of FRs, that thyroid hormone disruption is associated with FR exposure and that factors in the indoor environment, including products such as plastic toys, might increase FR exposure. Considering the limited amount of studies, and the variety of biological matrices, FRs, and risk- and protective factors, this review did not reveal a uniform pattern of toddler exposure across the different cohorts studied. More evidence is necessary and considering the feasibility of invasive sampling in young children, we suggest to emphasize research on non-invasive matrices.

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1. Introduction

Flame retardants (FRs) are endocrine disrupting chemicals (EDCs) that are used in household furniture and electronic devices to prevent the spread of fire. Exposure to these chemicals can disturb the hormone balance and prenatal exposure is associated with neurodevelopmental disorders and reproductive disorders (Bergman et al., 2013; Lyche et al., 2015). Exposure occurs through ingestion of contaminated house dust and food, inhalation of contaminated air, and dermal absorption. Studies with regard to exposure to FRs in adults include exposure on and around e-waste sites (Wu et al., 2016), ingestion of contaminated food (Zheng et al., 2012), and occupational exposure in, for example, firefighters (Park et al., 2015) and workers in foam and carpet industries (Stapleton et al., 2008). Due to differences in fire regulations, the magnitude of exposure varies between countries (Fromme et al., 2016; Hites, 2004).

Besides studies in adults, the effects of prenatal and neonatal exposure to FRs have been investigated. Prenatal FR exposure occurs because EDCs are able to reach the unborn child via the placenta and have been assessed previously in maternal blood (Frederiksen et al., 2010; Serme-Gbedo et al., 2016), in umbilical cord blood and placental tissue at birth (Chevrier et al., 2016; de Cock, Quaak, Sugeng, Legler and van de Bor, 2016; Frederiksen et al., 2010). The main source of neonatal and infancy exposure is through consumption of contaminated breast milk, which has been studied in numerous studies across Europe, the USA, the Pacific and Asia, as reviewed by Fromme et al. (2016). Several reviews reported health effects of prenatal exposure to polybrominated diphenyl ethers (PBDEs). Neurobehavioral alterations were found in animal studies (Branchi et al., 2003) and in human studies, disturbed thyroid hormone balance, mostly decreased thyroid hormone levels, and negative effects on IQ were observed (Czerska et al., 2013; Linares et al., 2015) and impaired language development were found. (Dzwilewski and Schantz, 2015).

Since human development does not stop at birth or at the end of the neonatal period, human exposure to FRs is not a one-time event but a cumulative process. Importantly, toddlerhood is a critical period for neurodevelopment and the development of the immune system. Toddler physiology makes them at risk for higher exposure,

for example their relatively high total body surface and higher respiratory rates compared to adults (Environmental Protection Agency, 2011; Phillips et al., 1993). Furthermore, toddlers are at an increased risk of exposure because of their specific behavior, such as often being close to the floor while crawling and learning to walk, and putting hands and objects in their mouths (mouthing behavior) (Environmental Protection Agency, 2011). This specific risk heightening behavior does not apply to the entire toddlerhood period, which lasts from 1 to 3 years, as after 24 months toddlers have reduced mouthing behavior (Groot et al., 1998) and are able to walk independently (Cioni et al., 1993; Jeng et al., 2008). Besides the role of age and age related behavior, other factors may increase or decrease exposure. For example the presence of electronic devices increases some FR congeners in indoor dust (Brandtsma et al., 2014), and hand washing decreases the amount of flame retardants on adult hands (Watkins et al., 2011). These conditions may apply for toddlers as well.

No overview of studies on toddler exposure and health effects exist. However, an overview is essential in order to determine to what extent exposure during toddlerhood affects short- and long term health. In this narrative systematic review our first aim was to summarize the literature on the magnitude of FR exposure in toddlers. Our second aims were to review the health effects of short- or long term and to define potential environmental, demographic or behavioral risk- or protective factors for toddler exposure, in order to provide guidance for policy makers to reduce indoor exposure to FRs and therefore to promote growing up healthy.

2. Methods

2.1. Study design

A systematic review was carried out in accordance to the Preferred Reporting Items for Systematic Review and Meta-analysis statement (PRISMA statement article) on applicable items. Three review questions were addressed: what is the magnitude of toddler exposure?; what is the health concern of toddler exposure?; what are sources of increased exposure, and as such are risk- and protective factors for toddler exposure? Details of the protocol for this

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