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Dynamics of persistent organic pollutants in obese adolescents during weight loss

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ABSTRACT

We have investigated the dynamics of various persistent organic pollutants (POPs) in the serum of 94 obese adolescents (34 boys and 60 girls: age range 11–19 years) before (0 *M*) and after 5 months (5 *M*) of undergoing weight loss treatment. Six groups of POPs, such as polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane and its metabolites (DDTs), chlordane compounds (CHLs), hexachlorocyclohexane isomers (HCHs), hexachlorobenzene (HCB) and polybrominated diphenyl ethers (PBDEs), were detected in all samples in the decreasing order of median levels: DDTs > PCBs > HCB > HCHs > CHLs > PBDEs. Levels and patterns of POPs between boys and girls at two time-points were similar. DDTs (0 *M*/5 *M*; median: 31/42 ng/g lw) and PCBs (0 *M*/5 *M*; median: 17/28 ng/g lw) were the major POPs. PCB 153 (0 *M*/5 *M*; 33/34% of the sum PCBs) was the most dominant PCB congener, followed by PCB 138 (0 *M*/5 *M*; 31/31%) and PCB 180 (0 *M*/5 *M*; 13/12%), respectively. The most important PBDE congeners were BDE 47 and 153, although total PBDE levels were low and ranged between 0.63 and 0.88 ng/g lw. In general, levels of POPs in the obese adolescents were lower than previously reported in Belgian adolescents and adults. Due to weight loss, serum levels (except PBDEs) increased significantly thereafter combined with a body weight decrease (from 4 to 42 kg). Serum concentrations increased by 1–3.5% per kilogram weight loss and 1–2.5% per BMI z-score loss for most POPs. To our knowledge, this is the first report on the dynamics of POPs in obese adolescents during weight loss. Lipid-soluble contaminants were released from adipose tissue into the blood leading to redistribution into the body. Whether the increase in the internal exposure to POPs may adversely influence health remains to be determined.

1. Introduction

Overweight and obesity are defined as abnormal or excessive fat accumulation that may impair health, and obesity has become a worldwide epidemic (Finucane et al., 2011; World Health Organization (WHO), 2012). As its prevalence is increasing exponentially (Hebert et al., 2013), obesity is rapidly becoming a major public health issue. Understanding the causes that lead to obesity and the prevention of obesity not only in adults, but also in children and adolescents, has been promoted as a public health priority to combat the obesity epidemic (La Merrill and Birnbaum, 2011; Pulgaron and Delamater, 2014). Over the last decades, obesity rates have indeed been rising among (European) adults and children (Lien et al., 2010). For school-age children, a first analysis, based on 2007–2008 data from 13 EU countries, finds that 24% of European children aged 6 to 9 are overweight (World Health Organization, 2010). For adolescents, 14 EU countries had trend data available, though some were based on self-reported measures with small samples (Lien et al., 2010). This is of importance as recent epidemiological studies show that obese children and adolescents tend to become obese adults with significant morbidity and mortality.

Though obesity is defined as excess body weight and fat accumulation, obese individuals vary in their body fat distribution, their metabolic profile and the degree of associated cardiovascular and metabolic risks (Van Gaal et al., 2006). This phenotypic variability might explain why the increasing prevalence of obesity cannot be attributed only to the classical risk factors such as changes in diet, lack of physical

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Table 1
Characteristics of the adolescents (median, minimum-maximum) at two different time points.

	Before weight loss (0 *M*)			After weight loss (5 *M*)			Differences between before and after weight loss*		
Sex	All	Boys	Girls	All	Boys	Girls	All	Boys	Girls
Number of participants	94	34	60	94	34	60	94	34	60
Age (years)	15 (11–18)	15 (12–18)	16 (11–18)	16 (11–19)	16 (12–19)	16 (11–19)	$p = 0.1842$	$p = 0.3331$	$p = 0.2195$
Height (cm)	165 (140–191)	167 (140–191)	164 (143–177)	166 (142–192)	169 (142–192)	165 (143–177)	$p = 0.2448$	$p = 0.3156$	$p = 0.3049$
Weight (kg)	98 (60–165)	101 (62–165)	96 (60–147)	82 (47–133)	83 (47–133)	81 (50–118)	$p < 0.0001$	$p < 0.0001$	$p < 0.0001$
BMI (kg/m^2)	36 (26–57)	36 (30–48)	36 (26–57)	29 (21–44)	27 (23–41)	30 (21–44)	$p < 0.0001$	$p < 0.0001$	$p < 0.0001$
BMI z-score	2.79 (1.76–3.76)	2.84 (2.16–3.49)	2.75 (1.76–3.76)	1.99 (0.77–3.55)	1.80 (0.90–3.03)	2.05 (0.77–3.55)	$p < 0.0001$	$p < 0.0001$	$p < 0.0001$
Cholesterol (g/L)	1.56 (0.95–2.97)	1.57 (0.95–2.44)	1.56 (0.98–2.97)	1.38 (0.88–2.24)	1.32 (0.88–1.87)	1.45 (1.08–2.24)	$p < 0.001$	$p < 0.0002$	$p = 0.1445$
Triglycerides (g/L)	0.76 (0.37–2.37)	0.65 (0.38–1.89)	0.81 (0.37–2.37)	0.67 (0.33–2.97)	0.61 (0.33–1.29)	0.72 (0.38–2.97)	$p = 0.1342$	$p < 0.02$	$p = 0.3828$
Total serum lipids (g/L)	4.90 (3.20–8.52)	4.77 (3.16–7.28)	4.90 (3.54–8.52)	4.50 (3.10–8.31)	4.19 (3.09–5.63)	4.76 (3.53–8.31)	$p < 0.003$	$p < 0.0002$	$p = 0.1859$

* Significant differences ($p < 0.05$) between before weight loss (0 *M*) and after weight loss (5 *M*).

activity, and underlying genetic susceptibility (La Merrill and Birnbaum, 2011). The exposure to certain persistent organic pollutants (POPs), chemicals that are stored in lipid-rich compartments, has been suggested to contribute to this obesity epidemics: some of these have the potential for long-term disruption of metabolic and endocrine processes and have been suggested to contribute to the obesity epidemic (Dirinck et al., 2011; Hectors et al., 2013). These so called environmental endocrine disrupting chemicals (EDCs) can influence adipogenesis and obesity (Heindel et al., 2015).

An important source of internal exposure to POPs is the storage compartment (adipose tissue) in the body (Malarvannan et al., 2013). When POPs enter the body through breast milk (for infants), food or other sources, they are primarily stored in adipose tissue and slowly released into the circulation to be eliminated over several years (Carpenter, 2013). Although early toxicological studies indicated that exposure to high levels of POPs is harmful to human health, it was recently observed that chronic exposure to low levels of POPs can also adversely affect the endocrine, immune, nervous and reproductive systems (Carpenter, 2013; Kodavanti and Loganathan, 2017). Given the evidence that POPs might alter systemic metabolic, endocrine, and immune system functions, it implies that elevated chemical concentrations in abdominal fat may alter the function of visceral organs through chemical signalling (Yu et al., 2011; La Merrill and Birnbaum, 2011; Lee et al., 2014).

The relationship between obesity and POPs is even more complex: weight loss might lead to increased blood concentrations of environmental pollutants and the greater the weight loss, the higher are the resulting POP concentrations in blood. In general, organochlorine compound levels increase upon weight reduction, irrespective of initial BMI (Wolff et al., 2005). Verhulst et al. (2009) demonstrated that intrauterine exposure to DDE and PCBs is associated with increased BMI during early childhood. Kim et al. (2011) reported that POPs may be involved in alterations of lipid and energy homeostasis and in dysfunction of the liver, and that even though weight reduction may be beneficial, the benefits appear to be slowed down or decreased by high POP levels. Several studies in obese adults demonstrated an elevation in blood levels in most POP levels between 3 and 12 months after intervention (Chevrier et al., 2000; Imbeault et al., 2001; Pelletier et al., 2002; Arguin et al., 2009; Kim et al., 2011; Dirtu et al., 2013; Rantakokko et al., 2015). Most mechanistic studies on obesity are conducted in adults and there is much less information collected from children or adolescents (Wang and Lobstein, 2006). Studying the link between POPs exposure and obesity in adolescents offers additional advantages. Measurements in adolescents may reflect “local” exposure (limited changing of residence) and are not influenced by direct occupational exposure. Due to their persistency, the elimination of POPs is a slow process and therefore their kinetics in obese adolescents is possibly different from their lean or adult obese counterparts.

There are several studies defining trends in the POP levels in obese adults during weight loss, but no information is available regarding POP levels in obese adolescents during weight loss treatment. The present study therefore aimed to obtain an overview of occurrence and levels of POPs in Belgian obese adolescents and to evaluate the dynamics of various POPs in the serum of obese individuals during weight loss treatment.

2. Materials and methods

2.1. Sample collection

Ninety-four ($n = 94$) adolescents were prospectively recruited when visiting the Zeepreventorium (ZEEP) between 2010 and 2011. The ZEEP is a rehabilitation medical centre at the Belgian coast for children and adolescents until 19 years who are suffering from a chronic disease, including obesity. All patients entered a conservative weight loss program with dietary and lifestyle counselling, including increased physical activity and psychological support. Blood samples were collected in the morning with patients in a fasting state in 10 mL vacutainer tubes without anticoagulants and were centrifuged at 3500 rpm for 15 min. The serum was divided into two aliquots: the first one was analysed for total lipids and other clinical measurements, and the second one was stored in glass tubes at −80 °C for POP analysis. Blood samples were taken before weight loss (0 *M*) and after five months (5 *M*) from 94 obese adolescents (mixed gender (34 boys and 60 girls): age range 11–19 years). This study was approved by the Ethical Committee of the Antwerp University Hospital/University of Antwerp (UZA approval number 9/40/200; Belgian Registry Number: B30020097009) and all participants provided their written informed consent. Participant's age, gender, total lipids, their demographic characteristics and relevant information are listed in Table 1.

2.2. Physical measurements

All anthropometric measures were taken in the morning with patients in a fasting state and undressed. At that time, they have also donated blood and urine samples. Height was measured to the nearest 0.5 cm and body weight was measured with a digital scale to the nearest 0.1 kg. Obesity in adolescents was defined as a BMI above the 97th percentile, according to International Obesity Task Force (IOTF) criteria (Cole and Lobstein, 2012). The Body mass index z-score, a validated measure of relative weight adjusted for child age and sex was also calculated given the adolescent's age, sex, BMI, and the appropriate