PCB concentrations in women based on breastfeeding history: NHANES 2001–2004

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A B S T R A C T

Data from the 2001–2004 National Health and Nutrition Examination Survey (NHANES) were used to evaluate serum concentrations of polychlorinated biphenyls (PCBs) in women of reproductive age, with or without a history of breastfeeding. Analytical data for PCBs 138, 153, and 180 were used along with responses to the NHANES Reproductive Health questions: [Have you] breastfed any of your children? and [What] number of children have been breastfed [for] at least 1 month? PCB concentrations were found to be significantly lower among 15–44 year old women who had a history of breastfeeding compared to those who had not breastfed any of their children. Based on data for 474 women, ages 15–44 years, mean serum PCB 138, 153, and 180 concentrations were 16.4, 21.4, and 14.3 ng/g lipid for women who have a history of breastfeeding, and 24.0, 30.0, and 21.4 ng/g lipid for women who have not breastfed, respectively. These results were weighted using the 2001–2004 sample weights provided by NHANES to represent over 27 million U.S. women. PCB concentrations were also lower among women who had breastfed multiple children. Mean serum PCB 138, 153, and 180 concentrations were 11.8, 15.2, and 10.1 ng/g lipid, respectively, for women 35–44 years who had breastfed six children and 22.7, 31.9, and 22.5 ng/g lipid, respectively, for women 35–44 years who had breastfed only one child. The results tend to support the long-standing hypothesis that depuration of PCBs may occur via breastfeeding.

1. Introduction

Polychlorinated biphenyls (PCBs) are a class of synthetic organic chemicals that are persistent, bioaccumulative, and toxic (ATSDR, 2000). They are characterized by a biphenyl structure to which up to ten chlorine atoms are attached. A total of 209 PCB congeners are possible based on the various positions and numbers of chlorine atoms on the biphenyl molecule. Before manufacturing of PCBs ceased in the United States in 1977, PCB mixtures were used in many industrial applications because of their insulating properties, chemical stability, and relative inflammability. For example, they were used widely in capacitors, transformers, and other electrical equipment as well as in plasticizers, surface coatings, caulk, inks, adhesives, flame retardants, and paints, and for various other applications (ATSDR, 2000). While PCBs are no longer produced in the United States, the population may still be exposed to them through contact with PCB-contaminated media. Ingestion of PCB-contaminated foods (e.g., fish, meat, and dairy products) has historically been considered to be the primary pathway of human exposure among the general population, but inhalation may also be an important contributor (Lehmann et al., 2015). Several studies have also reported that PCB body burdens are higher among individuals (e.g., sports or subsistence fishers) who consume fish from contaminated areas (Schwartz et al., 1983; Kostyniak et al., 1999; Hanrahan et al., 1999; Kearney et al., 1999; Fitzgerald et al., 1999).

After exposure occurs, PCBs are stored in body fats. They may accumulate over time and remain in the body for many years. Lactation may be one means of eliminating PCBs and reducing maternal body burden (Lehmann et al., 2014; ATSDR, 2000). Body burden may be estimated by measuring PCBs in blood/serum lipids, breast milk, or adipose tissue. Schwartz et al. (1983) observed that in a group of Michigan women, “PCB levels in serum increased with age, but were unrelated to social class, parity, or weight.” Schettgen et al. (2015) analyzed the blood plasma concentrations of PCB congeners 138, 153, and 180 in a population in Germany and observed increases in concentration as age increased. Park et al. (2007) and Hassine et al. (2013) also observed increases in serum PCB concentrations based on increases in age. PCB concentrations in breast milk have also been
found to be higher in older women (Rogan et al., 1986; Kostyniak et al., 1999). Rogan et al. (1986) noted that PCB concentrations in breastmilk were lower among women who had breastfed previously, and Kostyniak et al. (1999) observed an inverse relationship between PCB concentrations in breast milk and the total number of months of lactation over a lifetime. Schecter et al. (1998) observed a decrease in PCB concentrations in human milk over a two and a half year lactation period in a mother nursing twins, corresponding to a depuration rate of about 4% per month (Tuc et al., 2010). Tuc et al. (2010) reported a depuration rate of about 2.5% per month via breastfeeding in a population of Vietnamese women, and suggested that the lower depuration rate in this study may be a result of ongoing exposures. However, Sjödin et al. (2005) did not see a decrease in PCB concentrations in breast milk over a 3 month breastfeeding period, and Hooper et al. (2007) did not observe substantial reductions over a 6-month period. Thompson and Boekelheide (2013) evaluated mixed exposures to lead, mercury, and PCB using serum concentrations in women 16–49 years of age from NHANES 1999–2004. The odds ratio for women having body burdens of 2 or more of these chemicals above the median was 0.56 for women who had breastfed for at least one month, compared to the referent group of women who had never breastfed.

The purpose of this study was to evaluate data from the National Health and Nutrition Examination Survey (NHANES) to determine whether differences in serum PCB concentrations in reproductive aged women could be detected based on age and breastfeeding history.

2. Methods

NHANES examines the health and nutritional status of a sample of the United States population (NCHS, 2014). The survey is divided into two components: interview and examination. The survey interview portion includes “demographic, socioeconomic, dietary, and health related questions”, whereas the examination portion includes “medical, dental, and physiological measurements, and laboratory tests” (NCHS, 2014). Approximately 5000 individuals are interviewed and examined each year (NCHS, 2014); beginning in 1999, NHANES began measuring a variety of environmental chemicals in serum samples from a subset of the survey participants over 12 years of age (NCHS, 2016).

We used NHANES data for reproductive aged women to examine relationships between serum PCB concentrations and age, and differences in serum PCB concentrations based on breastfeeding history. While reproductive age has been defined in a variety of ways, we used ages 15–44 years to represent women of reproductive age (Moya et al., 2014; Kahn and Strakla, 2008). The use of this age range also allowed us to divide the data into three equal age range categories spanning 10 years each (i.e., 15–24, 25–34, and 35–44 years). PCBs 138, 153, and 180 were chosen for this analysis because these congeners have long biological half-lives and are frequently detected and quantified in serum (Schettgen et al., 2015). These three PCBs are typically present at the highest proportions relative to other congeners (Hansen, 1998; Pavuk et al., 2014) and have been the subject of numerous population studies worldwide (CDC, 2009, 2013; Heudorf et al., 2002; Pavuk et al., 2007). Also, among the PCB congeners evaluated in NHANES 2001–2004, these 3 congeners had the highest frequencies of detection.

Information on breastfeeding history was based on responses to the NHANES reproductive history questionnaire. Specifically, we used response data for the questions “[Have you] breastfed any of your children?” and “[What] number of children [have been] breastfed [for] at least 1 month?” (NCHS, 2004, 2006).

We explored NHANES data from every two-year cycle from 1999-2000 to 2013-2014 to determine whether both serum data on PCBs 138, 153, and 180 and questionnaire data pertaining to breastfeeding history were available for reproductive aged women. As shown in Table 1, only the 1999–2000, 2001–2002, and 2003–2004 data sets contained both types of data (i.e., serum PCB concentrations and questionnaire responses pertaining to breastfeeding history). We eliminated the 1999–2000 data set from further consideration due to high detection limits and low percentage of detections of PCBs 138, 153, and 180 compared to the 2001–2002 and 2003–2004 data sets (Table 2). In 2003–2004, NHANES reported PCBs 138 and 158 together because they co-eluted, but PCB 138 was reported as 138 alone in 2001–2002.

Data were available in the 2001–2002 data set for 279 women for PCBs 138, 153, and 180; 169 of these women had a history of breastfeeding, and 110 had no history of breastfeeding. For 2003–2004, data were available for 195 women for PCBs 138/158, 153, and 180; 115 of these women had a history of breastfeeding, and 80 had no history of breastfeeding. Women who had missing data for one or more PCB congeners, or refused to answer, or responded that they did not know on the breastfeeding history questionnaire were excluded from the data set. Although we initially analyzed the 2001–2002 and 2003–2004 data sets separately, we subsequently combined the two data sets to increase the number of observations. The primary focus of this paper is on the results of the 2001–2004 combined data set, but some of the data that were analyzed separately for years 2001–2002 and 2003–2004 are provided as supplemental information (see Supplemental Tables S1 to S4). Overall, using the combined data sets, there were data for 474 women: 284 (60%) with a history of breastfeeding, and 190 (40%) with no history of breastfeeding. Because PCBs accumulate over time, we also divided the data according to finer age groups for some of the analyses. The 2001–2004 data were available for 105 women ages 15–24 years, 151 women ages 25–34 years, and 218 women ages 35–44 years.

Because PCBs are lipophilic, we used the lipid-adjusted concentrations of PCBs 138, 153, and 180 in serum. Lipid-adjusted PCB data represent body burden better than unadjusted values (Axelrad et al., 2009). For PCB lipid-adjusted concentrations that were below the limit of detection, “the value for that variable is the detection limit divided by the square root of two” (NCHS, 2005, 2008). This has been found to be an acceptable method for treating non-detectable values in a data set of this sort (Hornung and Reed, 1990).

The NHANES 2001–2002 and 2003–2004 lipid-adjusted serum concentrations for PCBs 138, 153, and 180, along with the Demographic Variables and Sample Weights and Reproductive Health questionnaire data were downloaded from the CDC NHANES website and imported into SAS version 9.4 for Windows software (Version 9.4; SAS Institute Inc., Cary, NC). The PCB data were extracted from the NHANES file entitled “Dioxins, Furans, Coplanar PCBs” for 2001–2002 and the file named “Non-dioxin-like Polychlorinated Biphenyls” for 2003–2004. These files provided lipid-adjusted serum concentrations, along with the detection limits of each sample. The Demographic Variables and Sample Weights included gender and the age at screening adjudicated (in years). The Reproductive Health questionnaire data provided information on whether or not women breastfed any of their children and the number of children breastfed for at least one month. Because NHANES uses a complex survey design, PCB sample weights for 2001–2002 and 2003–2004 were applied to reduce potential bias and construct a data set that was representative of the U.S. population. In NHANES, “A sample weight is assigned to each sample person. It is a measure of the number of people in the population represented by that sample person in NHANES, reflecting the unequal probability of selection, nonresponse adjustment, and adjustment to independent population controls.” (CDC, 2016). Statistical analyses were conducted using SAS version 9.4.

We generated descriptive statistics for serum concentrations of PCB 138, 153, and 180 and the sum of the three PCBs by age group, and used correlation analyses to evaluate relationships between age and serum PCB concentrations. We also developed descriptive statistics for women based on their breastfeeding history. Because the data were skewed, we also used log-transformed data to estimate geometric
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