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The Centers for Disease Control and Prevention (CDC) conducted analyses for 34 polychlorinated biphenyl (PCB) congeners in blood samples collected from a statistically representative sample of the U.S. population during the National Health and Nutrition Examination Survey (NHANES) and reported overall population percentiles. Because the serum concentrations of many persistent organochlorine compounds are strongly age dependent, data were analyzed from the NHANES 2001–2002 sampling cycle to identify age-specific reference ranges for the measured congeners on a lipid-adjusted serum basis. In addition, reference ranges were estimated for the sum of the 34 measured PCB congeners. Because many congeners were frequently nondetectable, estimates for summed PCB levels are dependent upon the assumption used to replace nondetectable concentrations in the calculation. The effect of nondetects on the summed congeners totals is particularly strong for younger ages. The NHANES 2001–2002 PCB serum data demonstrate strong age-related trends, with older individuals displaying higher concentrations of most congeners and of summed PCB congeners. These age-specific reference ranges for PCB concentrations are critical for accurate interpretation of measured serum concentrations of PCB congeners in individuals.

In 2005, the Centers for Disease Control and Prevention (CDC) published the Third National Report on Human Exposure to Environmental Chemicals based on the National Health and Nutrition Examination Survey (NHANES) survey con-

ducted in 2001–2002. This report provides descriptive statistics for 34 individual polychlorinated biphenyl (PCB) congeners on both a wet weight (serum) and lipid-adjusted basis. These data are presented on a weighted basis to represent estimates for the civilian, noninstitutionalized U.S. population.

The CDC report provides summary statistics for PCB levels in both children (ages 12 to 19 yr) and adults (≥ 20 yr of age). However, the report does not provide any further analysis of age-specific distributions. When evaluating background levels of persistent organochlorine compounds, such as PCB congeners or dioxins, it is essential to compare serum levels on an age-specific basis because many of these compounds demonstrate strong trends with age (Heudorf et al., 2002; Patterson et al., 2004; Ferriby et al., 2007). Therefore, an analysis of the NHANES data from 2001–2002 was conducted to provide age-specific reference ranges for the individual congeners and total PCB levels based on the sum of these congeners.

METHODS

The National Center for Health Statistics provides access to data collected in the NHANES survey (NHANES, 2007). The data files are available in SAS transport file format. These files were downloaded and SAS was used to develop age-specific distributions. This analysis required both the demographics data for the study population (including statistical weighting information) and lab results for the 34 individual PCB congeners.

Serum concentrations (wet weight) and lipid-adjusted concentrations were available for each PCB congener. These data were extracted and sorted into 10-yr age groups. PCB samples were collected only on a subpopulation of individuals 12 yr of

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TABLE 1
Reference Values (50th, 95th Percentiles) by 10-Year Age Group for PCB Congeners Based on the NHANES 2001–2002 Data Set (Weighted)

Congener	Lipid-adjusted (ng/g) PCB serum levels by 10-yr age group (NHANES 2001–2002)																	
	12–19 yr		20–29 yr		30–39 yr		40–49 yr		50–59 yr		60–69 yr		70–79 yr		80+ yr			
	50th	95th	50th	95th	50th	95th	50th	95th	50th	95th	50th	95th	50th	95th	50th	95th		
52	*	22.9	*	14.2	*	16.0	*	19.6	*	10.7	*	11.9	*	18.8	*	14.7		
66	*	*	*	8.3	*	7.8	*	10.2	*	8.7	*	9.5	*	15.3	*	13.0		
74	*	9.9	*	10.2	5.0	15.8	7.3	23.2	10.9	32.7	16.6	42.8	20.2	48.5	30.4	72.5		
81	NC	NC	*	*	*	*	*	*	*	*	*	*	*	*	*	*		
87	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		
99	*	7.5	*	11.7	*	12.1	6.2	22.3	7.4	27.3	11.6	33.2	11.9	36.3	17.2	51.9		
101	*	*	*	*	*	*	*	*	*	*	*	*	*	5.7	*	*		
105	*	*	*	*	*	4.4	*	6.5	*	7.8	*	12.4	*	15.6	6.0	23.2		
110	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		
118	*	9.8	*	14.6	5.8	19.8	8.9	30.3	11.5	38.3	21.1	63.7	19.8	68.5	35.7	114.0		
126	NC	NC	0.02	0.05	0.02	0.06	0.03	0.07	0.03	0.11	0.04	0.14	0.04	0.18	0.06	0.28		
128	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		
138	5.4	23.1	9.0	34.5	16.4	46.9	25.5	91.7	33.7	87.0	48.0	113.0	54.2	147.0	72.3	204.0		
146	*	*	*	5.1	*	7.1	*	11.0	5.4	15.3	7.7	20.4	7.8	22.8	12.7	35.3		
149	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		
151	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		
153	7.7	31.9	11.2	39.6	22.6	63.8	37.7	110.0	49.2	129.0	62.4	147.0	74.9	190.0	99.5	245.0		
156	*	*	*	4.8	*	9.4	5.8	19.4	7.5	18.4	10.0	23.5	11.6	26.9	15.1	35.7		

age and older. Thus, no data exist for the first age group (0–9 yr), and the second age group (10–19 yr) was truncated at 12 yr of age.

Percentiles were calculated for each PCB congener on a lipid-adjusted basis in each age group. Summed PCB levels were derived by adding the 34 measured PCB congeners for each individual. Nondetectable measurements were addressed in two ways: by setting nondetects to equal the $\text{LOD}/\sqrt{2}$ or zero. In addition, individuals with missing values for specific congeners were included and assumed to be zero. Percentiles by 10-yr age groups were then calculated for summed PCB levels on a whole serum basis and on a lipid-adjusted basis.

RESULTS

Table 1 summarizes the 50th (median) and 95th percentile values for each PCB congener and summed PCB levels on a lipid-adjusted basis. These data were weighted in the same manner as the CDC report to represent the civilian, noninstitutionalized U.S. population.

Figure 1 presents the distribution of summed PCB levels by 10-yr age groups on a whole serum basis. The paired box plots indicate the estimated percentiles for the summed PCB congeners assuming either $\text{LOD}/\sqrt{2}$ or zero for nondetectable concentrations.

DISCUSSION

Both Table 1, summarizing the individual PCB congener data, and Figure 1, showing summed PCB levels, clearly demonstrate age-related trends in PCB blood concentrations on either a serum wet weight basis or a lipid-adjusted basis. Individual congener data were provided only on a lipid-adjusted basis. Lipid-adjusted values are considered to be of greater importance when comparing data across individuals or studies, since accounting for lipids in the blood reduces the potential for bias from nonfasted samples (Phillips et al., 1989).

Age-related trends are expected for persistent organochlorine compounds and are consistent with those seen in fish eaters in 1979 (Kreiss, 1985) and more recently in a German population with no known or identified exposures to PCB congeners (Heudorf et al., 2002). Kreiss (1985) reported a mean PCB serum concentration of 17.2 ppb ($\mu\text{g}/\text{L}$) with range of 3.2 to 158 ppb. Based on geometric mean concentrations of PCB blood levels, the lowest concentrations (approximately 10 ppb) were observed in the youngest age group (<1 to 9 yr of age) and the highest concentrations were found in those individuals >70 yr of age (between 27 ppb in females and 45 ppb in males), based on Figure 1 in Kreiss (1985). Heudorf et al. (2002) examined PCB serum concentrations in 624 individuals living in Germany in 1998. A quantitative decrease in PCB concentrations was observed in children up to 18 yr of age.

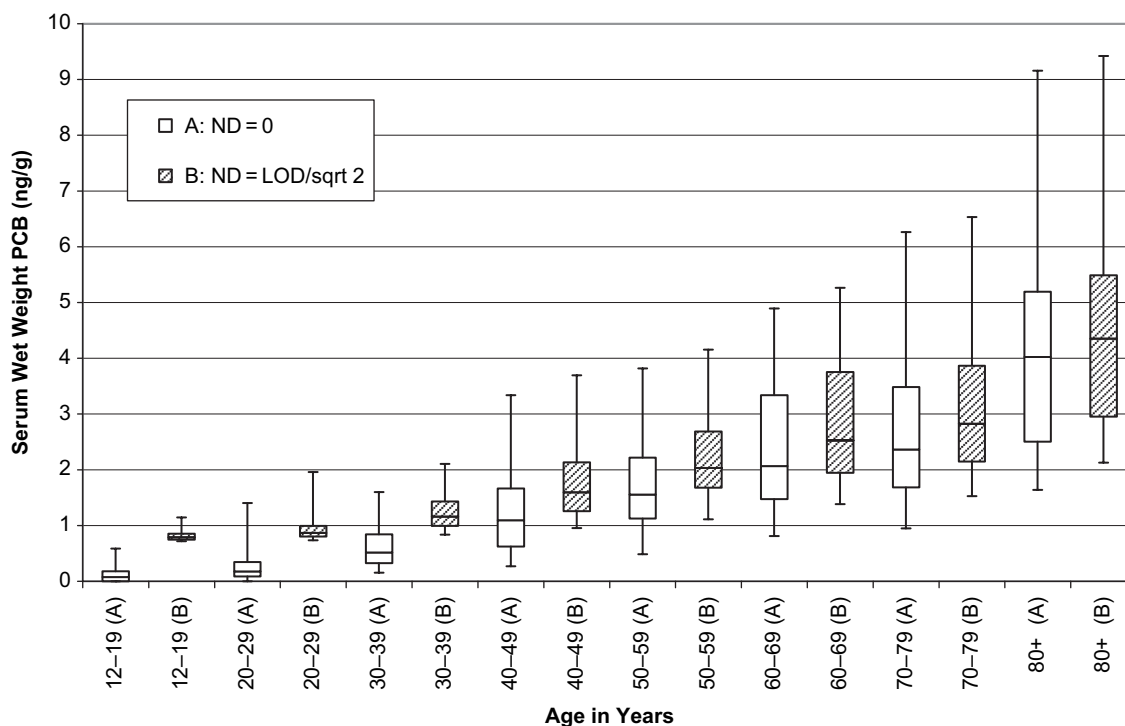


FIG. 1. Summed PCB levels by 10-yr age group based on NHANES 2001–2002 survey data. Box plots present weighted percentiles as follows: The box represents the interquartile range (25th to 75th percentiles), with the median indicated by the horizontal line in the box. Whiskers extend to the 5th and 95th percentiles. Boxes are presented for estimated percentiles under two assumptions for replacement of nondetectable (ND) concentrations: () ND=0; (B) ND= $\text{LOD}/\sqrt{2}$.

However, PCB levels increased with age among adults (>18 yr). Median PCB concentrations based on the sum of 3 congeners varied by age group, ranging from 0.66 µg/L in those 12 to <18 yr up to 4.04 µg/L for individuals >55 yr of age (Heudorf et al., 2002).

Age-specific reference levels are important for accurate interpretation of measured serum PCB concentrations. Relying on the CDC distributions for the entire adult population can be misleading. As seen in Figure 1, differences between the youngest age (12–19 yr) and the oldest (> 80 yr) age groups vary by at least a factor of 8. Thus, use of the 95th percentile concentration from the CDC total population when evaluating an older individual's measurement might result in mischaracterizing an individual's measured levels as elevated. Conversely, application of the same value to a young individual may result in mischaracterizing that individual's levels as normal when in fact their PCB levels are higher than expected for their age.

The NHANES data sets are superior to earlier efforts to characterize population concentrations of PCB levels based on ad hoc studies (see, for example, the data sets summarized in the ATSDR [2000] *Toxicological Profile for Polychlorinated Biphenyls*), both because (1) the statistically representative nature of the data sets and (2) the data are recent, reflecting general declines in the population. However, accurate use of the NHANES data sets requires consideration of the strong age-related trends, as discussed earlier. Further analyses need to be conducted on the NHANES data to evaluate the influence of other characteristics, including gender, race/ethnicity, smoking, and body mass index, on the measured concentrations in

the general population. CDC currently recommends that no statistical tests for significance of trends over time be conducted on these data because of the limited time frame of available sampling. However, the NHANES 2003–2004 data may be sufficient to warrant such analyses.

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