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**Urinary Concentrations of 2,4-Dichlorophenol and
2,5-Dichlorophenol in the U.S. Population (National
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Trends and Predictors**

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Urinary Concentrations of 2,4-Dichlorophenol and 2,5-Dichlorophenol in the U.S. Population (National Health and Nutrition Examination Survey, 2003–2010): Trends and Predictors

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Short running head: Exposure to dichlorophenols in the U.S. population

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Abstract

Background: 2,4-Dichlorophenol (2,4-DCP), 2,5-dichlorophenol (2,5-DCP) and their precursors are widely used in industry and in consumer products. Urinary concentrations of these dichlorophenols (DCPs) have been measured as part of four National Health and Nutrition Examination Survey (NHANES) cycles to assess the exposure to these compounds or their precursors among the U.S. general population.

Objectives: To identify predictors and evaluate trends in concentrations of DCPs according to race/ethnicity, age, sex, family income, and housing type.

Methods: We used analysis of covariance to examine associations of various demographic parameters and survey cycle with urinary concentrations of DCPs during 2003–2010. We also conducted weighted logistic regressions to estimate associations of DCP concentrations above the 95th percentile with housing type, race/ethnicity, and income.

Results: We detected DCPs in at least 81% of participants. Geometric mean (GM) urinary concentrations were higher for 2,5-DCP (6.1-12.9 $\mu\text{g/L}$) than 2,4-DCP (0.8-1.0 $\mu\text{g/L}$) throughout 2003–2010. Adjusted GM concentrations of the DCPs among children (age 6-11 years) and adults older than 60 years were higher than among adolescents and other adults. Adjusted GM concentrations among non-Hispanic whites were lower than among non-Hispanic blacks and Mexican Americans, though differences according to race/ethnicity were less pronounced among participants in high-income households. Among non-Hispanic blacks and Mexican Americans adjusted GM concentrations were lowest among high-income participants relative to other income groups, with a monotonic decrease with income among Mexican Americans. Type of housing and race/ethnicity were significant predictors of DCPs urinary concentrations above the 95th percentile. Furthermore, urinary DCP concentrations showed a downward trend since 2003.

Conclusions: Exposure to DCPs and their precursors was prevalent in the general U.S. population in 2003–2010. We identified age and race/ethnicity, family income, and housing type as predictors of exposure to these compounds.

Introduction

2,5-Dichlorophenol (2,5-DCP) is a major metabolite of 1,4-dichlorobenzene (1,4-D), which has been used as a chemical intermediate for the manufacture of dyes, pharmaceutical and agricultural products, and as a moth repellent and space deodorant for industrial and indoor home applications (IPCS 1989; National Library of Medicine 2013a). 2,4-Dichlorophenol (2,4-DCP) is primarily used in the production of phenoxy acid herbicides, such as 2,4-diphenoxyacetic acid (2,4-D) and for the synthesis of pharmaceuticals and antiseptics (National Library of Medicine 2013b). 2,4-DCP could enter the environment as a degradation product of triclosan, an antimicrobial agent (Canosa et al. 2005), and 2,4-DCP and 2,5-DCP can both be by-products of the chlorination of municipal drinking water and industrial waste water (National Library of Medicine 2013a; National Library of Medicine 2013b). The U.S. Environmental Protection Agency (EPA) considers dichlorophenols (DCPs) as hazardous pollutants (EPA 2012). General population exposure to DCPs and their precursors can occur through industrial and indoor air pollution, diet, and the use of pesticides and consumer products (National Library of Medicine 2013a; National Library of Medicine 2013b).

Chlorinated phenols are toxic for a wide range of wildlife organisms and humans (Hsiao et al. 2009; IPCS 1989; Takahashi et al. 2011). In 1987, the International Agency for Research on Cancer (IARC) classified 1,4-D as a carcinogen in animals (IARC 1999; National Toxicology Program 2011). The Agency for Toxic Substances and Disease Registry (ATSDR) and IARC classified 1,4-D as a suspected human carcinogen (ATSDR 2006; IARC 1999). Because of the potential adverse health effects upon exposure to these DCPs or their precursors (Buttke et al. 2012; Chevrier et al. 2012; Hsiao et al. 2009; Jerschow et al. 2012; Philippat et al. 2012; Twum

and Wei 2011; Wolff et al. 2008), assessing the prevalence of human exposure to these compounds is warranted.

Like many non-persistent chemicals, DCPs or their precursors can be rapidly metabolized via phase I (e.g., oxidation) or phase II (e.g., conjugation) biotransformations and eliminated in urine. The urinary concentrations of total (free plus conjugated) species of DCPs have been used as exposure biomarkers (Hill et al. 1995; Hissink et al. 1997). Urinary concentrations of 2,4-DCP and 2,5-DCP in the U.S. general population have been measured as part of the National Health and Nutrition Examination Survey (NHANES), conducted by the US Centers for Disease Control and Prevention (CDC) (CDC 2012). In the present study, we examine data from NHANES 2003–2004, 2005–2006, 2007–2008, and 2009–2010 (CDC 2012) to evaluate exposure trends during this eight-year period, as well as potential differences in urinary concentrations by race/ethnicity, age, sex, and income. Housing-related environmental hazards may affect health (CDC 2011a). Therefore, we also examined housing type as a predictor of the urinary concentrations of DCPs.

Materials and Methods

Urine samples analyzed for 2,4-DCP and 2,5-DCP were obtained from 10,426 participants aged 6 years and older from NHANES 2003–2010. CDC's National Center for Health Statistics Institutional Review Board reviewed and approved the NHANES study protocol. All participants gave informed written consent; parents or guardians provided consent for participants younger than 18 years of age (CDC 2006b). We quantified the urinary concentrations of 2,4-DCP and 2,5-DCP by on-line solid phase extraction coupled to isotope dilution-high performance liquid chromatography-tandem mass spectrometry (Ye et al. 2005). The LOD for 2,4-DCP was 0.2

µg/L for all four surveys; the LOD for 2,5-DCP was 0.1 µg/L (NHANES 2003–2004) or 0.2 µg/L (NHANES 2005–2010) (CDC 2012). Details of the analytical procedures used are publicly available on the NHANES website (CDC 2006a).

For statistical analyses, we used SAS (version 9.2, SAS Institute, Cary, NC) and SUDAAN (version 10, Research Triangle Institute, Research Triangle Park, NC) programs. For each NHANES two-year cycle, SUDAAN incorporates sample weights and design variables to account for the complex sample design of NHANES. We calculated the frequency of detection, the geometric mean (GM), and distribution percentiles for both the volume-based (in µg/L) and creatinine-corrected (in µg/g creatinine) concentrations. For concentrations below the LOD, as recommended for the analysis of NHANES data (CDC 2006a), we used a value equal to the LOD divided by the square root of 2 (Hornung and Reed 1990). Because DCP urinary concentrations were not normally distributed, we used the log₁₀ transformation. Statistical significance was set at $P < 0.05$.

We used analysis of covariance to examine the relations of various demographic parameters and survey cycle to log₁₀ transformed urinary concentrations of DCPs. Initial models included sex, age, race/ethnicity, family income, ln-transformed creatinine, and survey period, plus all possible two-way interactions. We categorized race/ethnicity on the basis of self-reported data as non-Hispanic black, non-Hispanic white, and Mexican American. We excluded 929 persons not defined by these racial groups in the analysis of covariance, but included these persons in the total population estimates. We stratified age, reported in years at the last birthday, in four groups (6–11, 12–19, 20–59, and 60+ years old). Additionally, we categorized family income based on the poverty income ratio (PIR, an index calculated by dividing family income by a poverty threshold specific to family size) (CDC 2011b) as below poverty (PIR < 1), low (PIR: 1-1.93),

middle (PIR: 1.93-3.71), and high (PIR > 3.71). We estimated the adjusted GMs using the regression equation with the intercept and regression coefficient for a given level of the categorical variable specified, and multiplying the beta coefficient for all other categorical covariates by their estimated weighted percentage distribution.

To reach the final reduced models, we used backward elimination with a threshold of $P < 0.05$ for retaining covariates and two-way interactions, using Satterwaite-adjusted F statistics. In addition, we evaluated potential confounding by covariates that were not significant predictors by adding each back to a model that included significant predictors only. If addition of one of these excluded variables caused a change in the β coefficient for any of the significant predictors of $\geq 10\%$, we re-added the variable to the model. The final regression model included the following significant predictors of both DCPs ($P < 0.01$): age, survey period, and the interaction of race/ethnicity and family income.

Housing type information, collected from the NHANES housing characteristics questionnaire, was only available for NHANES 2003–2004 and 2005–2006 cycles. We categorized the type of housing into four categories: apartment, single house, mobile home/dorm, and attached home. We calculated the distribution of housing type by race/ethnicity and family income categories. To evaluate the relationship between single-family housing and both income and race/ethnicity, we used weighted logistic regression with housing type as the dependent variable (1, single family house; 0, other type [i.e., multiunit] housing) and income level, race/ethnicity and their interaction terms as independent variables.

To investigate the association between the likelihood of DCP concentrations being above the 95th percentile and type of housing, we first conducted weighted logistic regressions using type

of housing (single house, apartment, mobile home/dorm, attached home) as the independent variable and a dichotomous variable to indicate whether the DCP concentration was above or below the 95th percentile as the dependent variable. Because the effect estimates for apartment, attached home, or mobile home/dorm were similar (data not shown), we collapsed housing type into “single house” and “multiunit house,” and run a second set of logistic regression models using the revised housing type categories adjusted by race/ethnicity (Mexican American, non-Hispanic white, non-Hispanic black, other) and income level.

We used the publicly available NHANES biomonitoring data on triclosan (CDC 2013) to determine weighted Pearson correlations between log₁₀-transformed urinary concentrations of 2,4-DCP and triclosan for NHANES 2003–2010 participants. For a subset of NHANES 2003–2004 and 2005–2006 adult participants (20–59 year old), we also determined weighted Pearson correlations among log₁₀-transformed DCP concentrations and publicly available NHANES blood concentrations of 1,4-D (CDC 2013).

Results

2,4-DCP (81.2-90.5%) and 2,5-DCP (97.4-98.3%) were frequently detected during the four survey periods examined, with GMs ranging from 0.803 µg/L to 1.04 µg/L for 2,4-DCP, and 6.1 µg/L to 12.9 µg/L for 2,5-DCP (Table 1). Distributions according to NHANES cycle, age, sex, and race/ethnicity are provided in Supplemental Material Tables S1 and S2 (for 2,5-DCP and 2,4-DCP, respectively) and Tables S3 and S4 (for creatinine-corrected DCPs). The urinary concentrations of 2,5-DCP and 2,4-DCP among NHANES 2003–2010 participants (N = 10,426) were highly correlated (Pearson correlation coefficient (R) = 0.95, P < 0.0001); by contrast, the correlation between the urinary concentrations of 2,4-DCP and triclosan, another chlorinated

chemical monitored in NHANES, was relatively low ($R = 0.35$, $P < 0.0001$). Furthermore, 1,4-D blood concentrations and urinary DCP concentrations were correlated among the 1,381 NHANES 2003–2004 and 2005–2006 adult participants with available data (2,5-DCP: $R = 0.74$; 2,4-DCP: $R = 0.69$, both $P < 0.0001$).

Estimated GM concentrations of DCPs and corresponding 95% CI (derived using weighted values for other model covariates) are listed in Table 2, and p-values for pair-wise comparisons between categories of each model predictor are provided in Supplemental Material, Table S5. Based on models adjusted for survey cycle and race/ethnicity \times family income, GM concentrations of both 2,4-DCP and 2,5-DCP were significantly higher among 6-11 year old children and older adults (≥ 60 years of age) than among 12-19 or 20-59 year old participants (all $P < 0.01$). Adjusted GM concentrations of 2,5-DCP declined from 12.27 $\mu\text{g/L}$ (NHANES 2003–2004) to 6.07 $\mu\text{g/L}$ (NHANES 2009–2010) (Table 2, Figure 1). 2,4-DCP concentrations also decreased over time, though the decline was not monotonic and was not as pronounced.

There was little variation in adjusted DCP concentrations among non-Hispanic whites according to income (Table 2, Figure 2, and Supplemental Material, Table S5). Among Mexican Americans, DCPs decreased monotonically with increasing family income, from 31.95 $\mu\text{g/L}$ (95% CI: 22.54, 45.3) for those below poverty to 9.28 $\mu\text{g/L}$ (95% CI: 6.12, 14.08) in the highest income group for 2,5-DCP, and from 1.95 $\mu\text{g/L}$ (95% CI: 1.86, 2.04) to 0.95 $\mu\text{g/L}$ (95% CI: 0.83, 1.07) for 2,4-DCP (both $P < 0.001$). DCP concentrations among non-Hispanic blacks also were lowest among those with the highest incomes, but the highest concentrations were in the low-income group (Figure 2). DCP concentrations were consistently lower in non-Hispanic whites than in Mexican Americans or non-Hispanic blacks, regardless of income, though the

differences were not as pronounced among the high-income participants, and no longer statistically significant for Mexican Americans and non-Hispanic whites. Concentrations of both DCPs were higher among Mexican Americans than non-Hispanic blacks among those below the poverty line, but were higher among non-Hispanic blacks than Mexican Americans in all other income groups. Non-Hispanic whites lived in single houses more often (75.2 %) than Mexican Americans (60.5%) or non-Hispanic blacks (52.5%) (see Supplemental Material, Table S6). The percentage of people living in apartments or attached family housing decreased as family income increased, from 51.3 % to 28.8 % for non-Hispanic blacks, and from 32.8 % to 12.4 % for Mexican Americans (Supplemental Material, Table S7). Among those with high incomes, fewer Mexican Americans (12.4 %) than non-Hispanic blacks (28.8 %) reported living in apartments or attached family houses.

Compared with non-Hispanic blacks, non-Hispanic whites and Mexican Americans were 1.95 times (95%CI: 1.44, 2.66) and 1.66 times (95%CI: 1.01, 2.74) more likely to live in single family houses, respectively, based on logistic regression models adjusted for income. Compared with participants living below the poverty level, the odds of living in a single-family house increased with income (OR [95% CI] were 1.62 [1.12, 2.35]; 3.26 [2.18, 4.89]; and 5.27 [3.5, 7.92] for low, middle, and high income categories, respectively). However, associations between living in a single-family home and race/ethnicity did not differ significantly according to income, and vice versa (data not shown).

The odds of having urinary DCP concentrations above the 95th percentile in NHANES 2003–2004 and 2005–2006 were significantly associated with type of housing (single versus multiunit) and race/ethnicity, but not with income. After adjustment for race/ethnicity, participants living in multiunit housing were about 1.5 times more likely than participants living in single family

houses to have urinary concentrations of both DCPs above the 95th percentile (Table 3). Compared with non-Hispanic whites, Mexican Americans, non-Hispanic blacks, and persons of other races were 1.5-4.7 and 2.0-6.0 times more likely to have 2,4-DCP and 2,5-DCP concentrations above the 95th percentile, respectively (Table 3).

Discussion

The detection of 2,4-DCP and 2,5-DCP in at least 81% of the samples from the four NHANES cycles examined suggest that exposure to these compounds or their precursors was widespread among the U.S. general population during 2003–2010. Depending on the survey cycle, the GM concentration of 2,5-DCP was 6 to 10 times greater than that of 2,4-DCP. Animal studies suggest that both 1,4-D and 2,4-D (precursors of 2,5-DCP and 2,4-DCP, respectively) metabolize within hours and thus have short half-lives (National Library of Medicine 2013a; National Library of Medicine 2013b). Therefore, the differences between the GM urinary concentrations of 2,4-DCP and 2,5-DCP are likely related to different applications or production volumes of these two chemicals and their precursors. For example, the production volume of 2,4-DCP in the United States is lower than that of 2,5-DCP (EPA 2012; National Library of Medicine 2013a; National Library of Medicine 2013b; National Toxicology Program 2011).

Of interest, degradation of triclosan in chlorinated water may result in 2,4-DCP (Canosa et al. 2005). However, the relatively low correlation between the urinary concentrations of 2,4-DCP and triclosan ($R = 0.35$) suggests that triclosan is not the main source of exposure to 2,4-DCP in these NHANES participants. The high correlation between 1,4-D concentrations in blood and urinary concentrations of 2,5-DCP ($R = 0.74$) supports the likelihood that consumer products containing 1,4-D are an important source of exposure, and supports the use of 2,5-DCP as a

biomarker for exposure to 1,4-D not only in occupational settings (Hsiao et al. 2009), but also among the general population. High correlations between urinary concentrations of 2,5-DCP and 2,4-DCP ($R = 0.95$) and between urinary DCPs and blood 1,4-D concentrations among NHANES participants suggest that people might be exposed to 2,4-DCP and 2,5-DCP through a common source (Lores et al. 1981).

Regardless of survey cycle, the adjusted GM of DCPs among children and older adults were significantly higher than for the other age groups. Although the reason for this finding is not clear, differences in lifestyles and/or metabolism of children and seniors may play a role (EPA 2008).

Adjusted GM concentrations of 2,5-DCP and 2,4-DCP both decreased between 2003–2004 and 2009–2010 NHANES cycles based on models adjusted for age and race/ethnicity-income. Although 2,4-DCP, 2,5-DCP and 1,4-D are all high production volume chemicals, the production volume of 1,4-D decreased since 2002 (EPA 2012). According to reports filed under the EPA's Toxic Substances Control Act Inventory Update Rule, U.S. production plus imports of 1,4-D totaled 50–100 million pounds between 1990 and 2002, but decreased to 10–50 million pounds in 2006 (EPA 2012; National Toxicology Program 2011). This downward trend usage of 1,4-D may have contributed to the 50.5% decrease in the adjusted GM of 2,5-DCP from 2003–2004 to 2009–2010. For 2,4-DCP, for the same time period, the downward trend of adjusted GM of 2,4-DCP (19.8%) was not as pronounced as for 2,5-DCP.

Of interest, we found that housing type was significantly associated with the likelihood of having urinary DCP concentrations above the 95th percentile. Specifically, we observed that, after adjusting for race/ethnicity, participants living in multiunit houses (i.e., apartments, attached

homes, mobile homes/dormitories) were about 1.5 times more likely than participants living in single family houses to have urinary DCP concentrations above the 95th percentile. Indoor air quality in a single house is most likely unique to the home. By contrast, in apartments or in other types of attached housing, multiple dwellings may share, at least to a certain extent, the air quality because air may circulate among the closely connected living spaces. For example, evidence exists of secondhand smoke exposure in multiunit housing (King et al. 2010; Van Deusen et al. 2009). Our findings suggest that indoor air may be an important source of exposure to DCPs or their precursors (e.g., 1,4-D), particularly for people who live in close proximity to one another in multiunit housing.

Interestingly, Mexican Americans, non-Hispanic blacks, and persons of other races were 1.5-4.7 times more likely to have urinary 2,4-DCP concentrations above the 95th percentile, and 2.0-6.1 times more likely to have 2,5-DCP concentrations above the 95th percentile, than non-Hispanic whites. Because exposure to DCPs and their metabolites can occur through air inhalation, dermal contact, and ingestion of food and drinking water (National Library of Medicine 2013a; National Library of Medicine 2013b), associations with type of housing and race/ethnicity may be confounded by socioeconomic factors. For example, people living in multiunit housing might be more likely to consume food or drinking water contaminated with DCPs or their precursors than people living in single unit households. Also, people living in single households in rural areas (e.g., farms) or in suburban settings may experience different exposures to DCPs from usage of pesticides, insecticides, or disinfectants. Unfortunately, because NHANES participants' housing location information is confidential, we cannot differentiate suburban or rural settings from the available data. Nonetheless, because the US population living in farms today is rather limited (16

% in 2011) (US Census 2013), our findings should be generalizable to the US general population that for the most part do not live in farms.

Furthermore, adjusted GM concentrations of DCPs among non-Hispanic whites were consistently lower than among non-Hispanic blacks and Mexican Americans, though these differences, particularly for non-Hispanic whites and Mexican Americans, were not as pronounced among participants in high income households. On the other hand, adjusted GM of DCPs among non-Hispanic blacks and Mexican Americans were lowest among high-income participants relative to other income groups, with a monotonic decrease with income among Mexican Americans. Of interest, regardless of household income, non-Hispanic whites lived in single houses more often than persons of other race/ethnicities. Furthermore, the percentage of non-Hispanic blacks and Mexican Americans living in apartments or in attached family housing decreased considerably when family income increased. Also, fewer Mexican Americans reported living in apartments or attached family houses than non-Hispanic blacks in the high income category. Taking into consideration the above factors, we speculate that as household income increases living in single houses rather than in multiple dwellings may have contributed to the downward trend of adjusted GM of DCPs for non-Hispanic blacks and, most evident, for Mexican Americans. It is also possible that low household income minority participants use room deodorizers and moth repellents to a greater extent than other population groups, and indoor air concentrations of 1,4-D could exceed outdoor concentrations by at least an order of magnitude when room deodorizers and moth-control products are used (National Toxicology Program 2011).

Conclusions

In summary, data from NHANES 2003–2010 suggest widespread exposure of the general U.S. population to DCPs or their precursors. The downward trend of DCPs concentrations, particularly for 2,5-DCP, since 2003 suggest decreasing exposures of the U.S. general population to DCPs and their precursors likely related to decreases in production volumes of these compounds. We also observed differences in the adjusted GM concentrations of DCPs by age and race/ethnicity, and a downward trend of adjusted GM DCPs concentrations for non-Hispanic blacks and Mexican Americans as family income increased. Housing type was a significant predictor of DCP urinary concentrations above the 95th percentile suggesting that indoor air might be a likely route of human exposure to DCPs or their precursors. However, some of the differences above may also be partially related to socioeconomic disparities. The widespread exposure of the general U.S. population to DCPs, the differences in exposure by age, race/ethnicity, housing type, and socioeconomic status, and the potential adverse health effects from exposure warrant additional research.

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Table 1. Geometric mean and selected percentiles urinary concentrations (95th CI) in µg/L, and detection of frequency of 2,4-DCP and 2,5-DCP in the U.S. population 6 years of age and older: Data from NHANES 2003–2010^a.

Variable	NHANES 2003–2004	NHANES 2005–2006	NHANES 2007–2008	NHANES 2009–2010
2,5-DCP				
Geometric Mean	12.90 (10.10, 16.30)	9.55 (6.67, 13.70)	9.04 (7.22, 11.30)	6.10 (4.94, 7.53)
50 th percentile	10.50 (8.00, 14.20)	8.10 (5.60, 11.50)	6.60 (5.50, 8.30)	4.70 (3.70, 5.90)
95 th percentile	21.30 (14.10, 29.50)	11.9 (7.00, 20.40)	12.6 (9.00, 18.10)	8.80 (6.40, 15.70)
Frequency of detection (%)	98.2	98.2	98.3	97.4
2,4-DCP				
Geometric Mean	1.04 (0.90, 1.21)	0.95 (0.79, 1.13)	0.97 (0.85, 1.11)	0.80 (0.73, 0.89)
50 th percentile	0.90 (0.80, 1.10)	0.80 (0.70, 1.00)	0.80 (0.70, 0.90)	0.70 (0.70, 0.80)
95 th percentile	21.30 (14.10, 29.50)	11.9 (7.00, 20.40)	12.60 (9.00, 18.10)	8.80 (6.40, 15.70)
Frequency of detection (%)	81.2	87.5	90.5	85.9

^aNote: Sample size (N) is 2525 (2003-2004), 2548 (2005-2006), 2604 (2007-2008), and 2749 (2009-2010).

Table 2. Adjusted GM concentrations (95% CI) of 2,4-DCP and 2,5-DCP (in µg/L) according to age, NHANES cycle, and race/ethnicity-family income (NHANES 2003–2010)^a.

Variable	Sample Size	2,5-DCP Adjusted GM (95 th CI) (µg/L)	2,4-DCP Adjusted GM (95 th CI) (µg/L)
Age group (years)			
6-11	1474	10.57 (8.93, 12.52)	1.12 (1.08, 1.16)
12-19	2245	7.79 (6.59, 9.19)	0.88 (0.84, 0.91)
20-59	4480	8.32 (7.44, 9.31)	0.88 (0.85, 0.90)
60+	2227	10.91 (9.34, 12.74)	1.06 (1.02, 1.10)
NHANES cycle			
2003–2004	2525	12.27 (10.10, 14.9)	1.01 (0.94, 1.07)
2005–2006	2548	9.5 (7.12, 12.69)	0.95 (0.90, 1.010)
2007–2008	2604	8.71 (7.17, 10.58)	0.97 (0.92, 1.01)
2009–2010	2749	6.07 (5.05, 7.30)	0.80 (0.77, 0.84)
Race/ethnicity by family income^b			
Mexican American: Below poverty	748	31.95 (22.54, 45.30)	1.95 (1.86, 2.04)
Mexican American: Low	695	23.02 (16.60, 31.91)	1.69 (1.61, 1.77)
Mexican American: Middle	467	18.83 (12.87, 27.56)	1.40 (1.30, 1.50)
Mexican American: High	235	9.28 (6.12, 14.08)	0.95 (0.83, 1.07)
Non-Hispanic white: Below poverty	607	7.98 (6.37, 10.00)	0.86 (0.80, 0.92)
Non-Hispanic white: Low	935	6.71 (5.49, 8.20)	0.74 (0.69, 0.79)
Non-Hispanic white: Middle	1078	6.47 (5.38, 7.80)	0.80 (0.77, 0.84)
Non-Hispanic white: High	1551	6.21 (5.46, 7.06)	0.79 (0.75, 0.82)
Non-Hispanic black: Below poverty	653	26.02 (19.81, 34.16)	1.53 (1.44, 1.62)
Non-Hispanic black: Low	612	31.56 (23.39, 42.57)	1.83 (1.74, 1.92)
Non-Hispanic black: Middle	577	26.55 (20.82, 33.87)	1.69 (1.62, 1.76)
Non-Hispanic black: High	435	20.70 (15.95, 26.88)	1.27 (1.18, 1.36)

^aAdjusted GMs estimated using the regression equation with the intercept and regression coefficient for a given level of the categorical variable specified, and multiplying the beta coefficient for all other categorical covariates by their estimated weighted percentage distribution. ^bFamily income: Below poverty (poverty income ratio < 1), Low (poverty income ratio: 1-1.93), Middle (poverty income ratio: 1.93-3.71), High (poverty income ratio > 3.71).

Table 3. Adjusted odds ratios (95% CI) of the likelihood of participants having 2,4-DCP and 2,5-DCP urinary concentrations above the 95th percentile (NHANES 2003–2004 and NHANES 2005–2006).

Variable	2,5-DCP	2,4-DCP
Type of Housing^a		
Multiunit house	1.48 (1.13, 1.93)	1.49 (1.16, 1.91)
Single house (reference)	1.00	1.00
Race/ethnicity		
Mexican American	6.05 (3.38, 10.82)	4.73 (2.65, 8.41)
Non-Hispanic black	5.80 (3.36, 10.00)	4.30 (2.69, 6.89)
Other	2.04 (0.95, 4.37)	1.53 (0.68, 3.43)
Non-Hispanic white (reference)	1.00	1.00

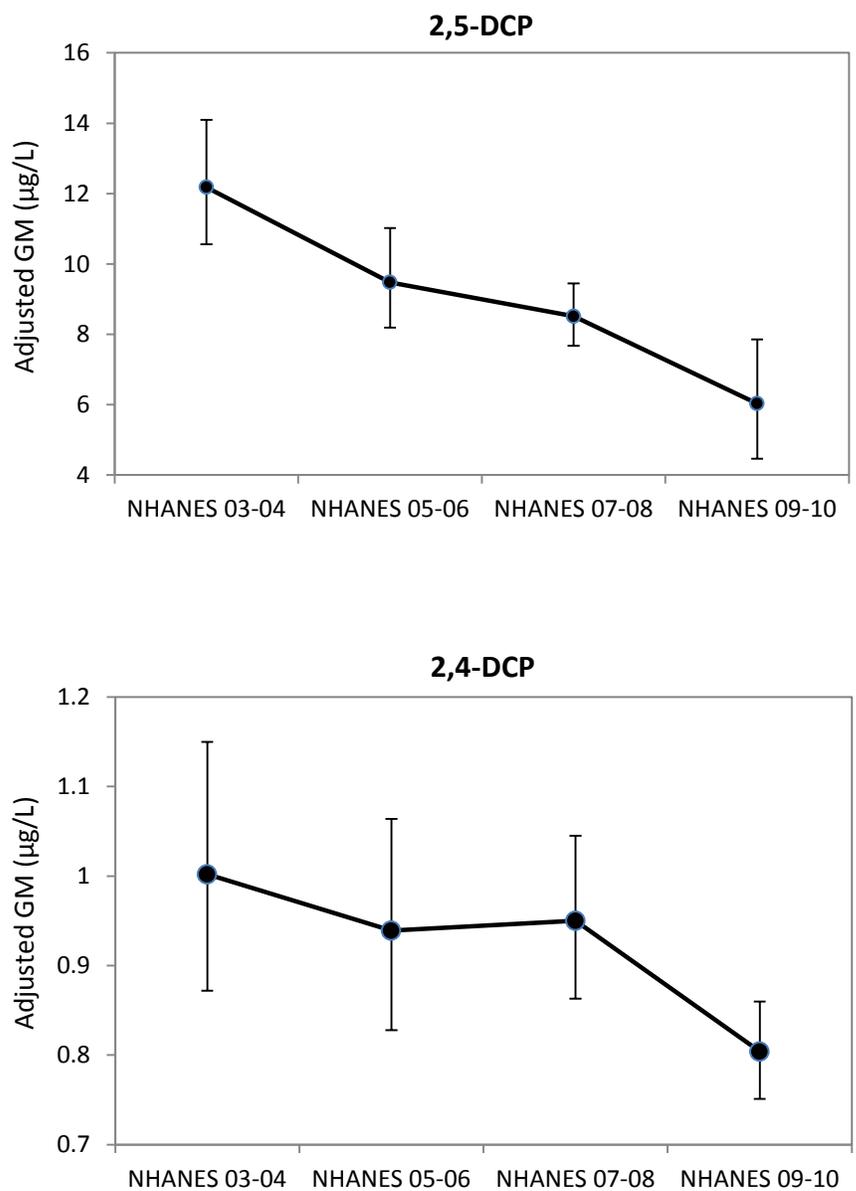
^aMultiunit house includes apartments, attached homes, and mobile homes or dormitories.

Figure Legends

Figure 1. Temporal trend for the adjusted geometric mean urinary concentrations of 2,4-DCP and 2,5-DCP. The error bars represent the 95% confidence intervals.^a ^aAdjusted GMs estimated using the regression equation with the intercept and regression coefficient for a given level of the categorical variable specified, and multiplying the beta coefficient for all other categorical covariates by their estimated weighted percentage distribution.

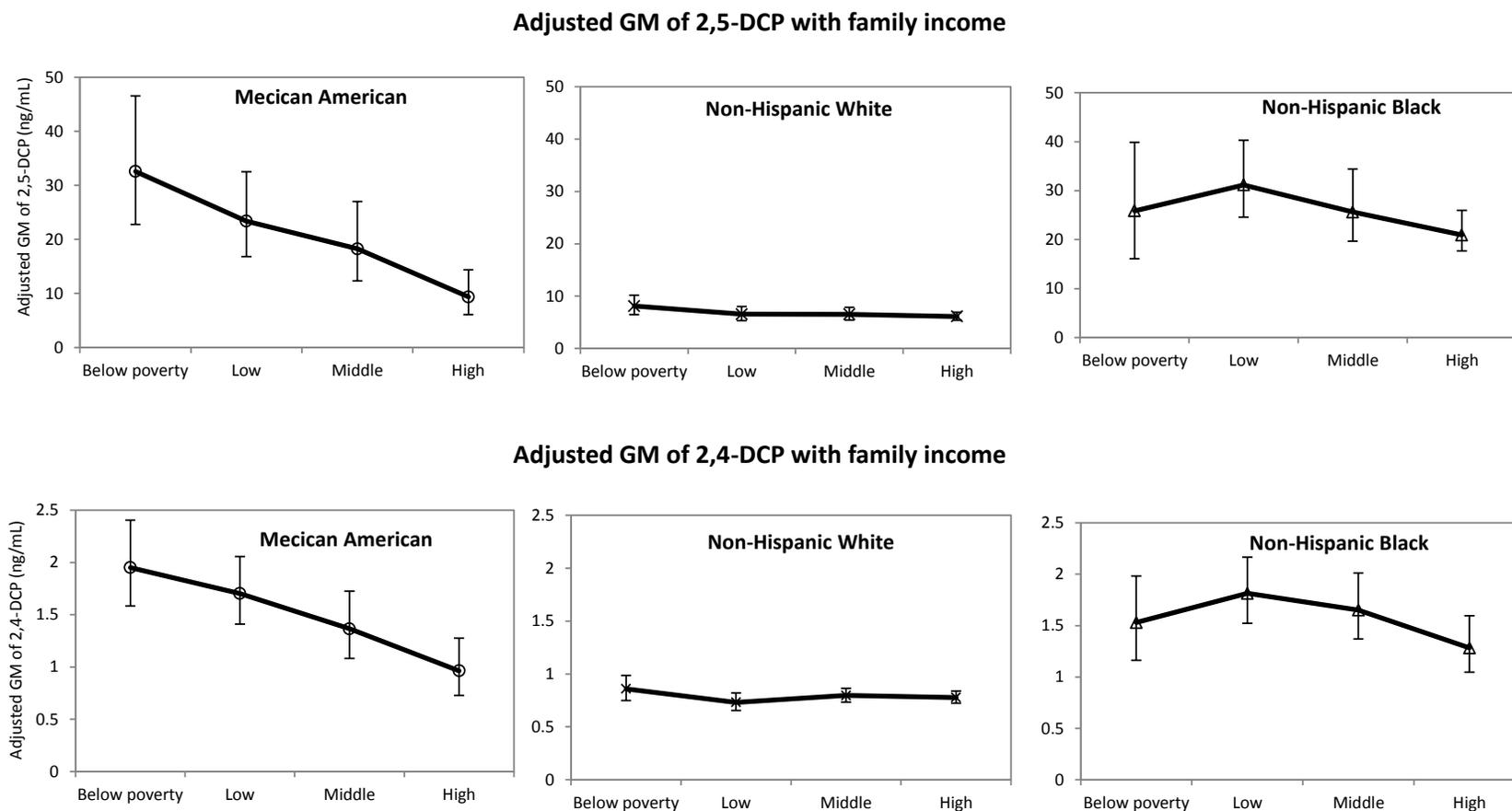
Figure 2. Adjusted geometric mean urinary concentrations of 2,4-DCP and 2,5-DCP by family income categories. The error bars represent the 95% confidence intervals.^{a,b} ^aFamily income categories: Below poverty (poverty income ratio <1), Low (poverty income ratio: 1-1.93), Middle (poverty income ratio: 1.93-3.71), High (poverty income ratio >3.71). ^bAdjusted GMs estimated using the regression equation with the intercept and regression coefficient for a given level of the categorical variable specified, and multiplying the beta coefficient for all other categorical covariates by their estimated weighted percentage distribution.

Figure 1. Temporal trend for the adjusted geometric mean (GM) urinary concentrations of 2,4-DCP and 2,5-DCP. The error bars represent the 95% confidence intervals^a.



^aAdjusted GMs estimated using the regression equation with the intercept and regression coefficient for a given level of the categorical variable specified, and multiplying the beta coefficient for all other categorical covariates by their estimated weighted percentage distribution.

Figure 2. Adjusted geometric mean (GM) urinary concentrations of 2,4-DCP and 2,5-DCP by family income categories. The error bars represent the 95% confidence intervals^{a,b}.



^aFamily income categories: Below poverty (poverty income ratio <1), Low (poverty income ratio: 1-1.93), Middle (poverty income ratio: 1.93-3.71), High (poverty income ratio >3.71).

^bAdjusted GMs estimated using the regression equation with the intercept and regression coefficient for a given level of the categorical variable specified, and multiplying the beta coefficient for all other categorical covariates by their estimated weighted percentage distribution.