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The Association between the Social Determinants of Health and Urinary Phthalates among Adults: NHANES 2009-2018

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The Association between the Social Determinants of Health and Urinary Phthalates among Adults: NHANES 2009-2018

By

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B.S., University of Florida, 2020

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An abstract of
A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
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2022

Abstract

The Association between the Social Determinants of Health and Urinary Phthalates among Adults: NHANES 2009-2018

By Brianna Binion

Background: Phthalates are industrial chemicals used to make consumer products softer and more malleable. Phthalates are commonly found in food packaging, fragrances, pharmaceuticals, seat fabrics and interior trim of automobiles.

Methods: This study included five National Health and Nutrition Examination Survey cycles from 2009 to 2018. After limiting the study to the adult population 18 years and older that had complete information on five urinary phthalates concentrations, we had a total of 9,318 participants. The phthalate concentrations were obtained from spot urine samples. Data for education, income, and marital status were obtained from the NHANES participant demographic questionnaire. Multiple linear regression models were used to evaluate the association between income, education, and marital status and phthalate metabolites after controlling for important confounders.

Results: In this study, higher income levels were positively associated with mono carboxy-isononyl, mono carboxy-isoctyl, mono-2-ethyl-5-carboxypentyl, and mono-benzyl concentrations. In contrast, higher educational attainment was inversely associated with mono-2-ethyl-5-carboxypentyl phthalate, mono-n-butyl, and mono-benzyl. In addition, being single or never married was inversely associated with urinary levels of mono carboxy-isononyl, carboxy-isoctyl, mono-2-ethyl-5-carboxypentyl, and mono-benzyl.

Conclusion: In summary, in this national representative sample of US adults, we observed significant positive associations between income and mono carboxy-isononyl and mono carboxy-oxyoctyl. In contrast, we observed inverse associations between income and mono-2-ethyl-5-carboxypentyl, mono-n-butyl and mono-benzyl. Further research is needed to determine if other phthalates are associated with the social determinants of health.

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Table of Contents

Background

Endocrine-disrupting chemicals (EDCs), also referred to as obesogens, are chemicals found in our food, water, and other items we use daily. The consumer market currently sells over 100,000 artificial chemicals, and a small subset has endocrine-disrupting potential. For example, organochlorine pesticides, polychlorinated biphenyls (PCBs), bisphenol A (BPA), alkylphenols, and phthalates can mimic the actions of estrogen[1]. In addition, many endocrine disruptors may interfere with other endocrine axes, including the testis, adrenal, and thyroid hormone systems[1]. Endocrine disruptors can also alter lipid homeostasis to increase the production of adipose cells[7].

Phthalates are industrial chemicals used to make consumer products softer and more malleable[5]. Phthalates are found in food packaging, fragrances, pharmaceuticals, seat fabrics and interior trim of automobiles, and other products[5, 6] (Figure 1). High molecular weight (HMW) phthalates are used to produce polyvinyl chloride (PVC) plastics for food packaging, building materials, and medical devices[11]. Low molecular weight (LMW) phthalates are used to create personal care products (e.g., perfumes, lotions, cosmetics, and shampoo), paints, and adhesives[11]. Phthalates are continuously emitted from PVC and plastic materials, resulting in indoor air contamination, house dust, or food containers[11]. As a result, the primary method of HMW phthalate exposure is ingestion of contaminated food or dust. In contrast, the primary way of LMW phthalate exposure is inhalation or dermal contact[11].

Exposure to phthalates may increase an individual risk of various health issues. For example, phthalates are capable of transplacental transition, and they can exert their toxic effects within embryonic and fetal development[10]. Phthalates affect ovarian functions leading

to full-spectrum disorders associated with reproduction[10]. Also, phthalates interfere with male reproductive system development, such as testicle function, leading to testicular dysgenesis syndrome (TDS)[10]. Additionally, phthalates act as anti-androgens to disrupt the hormonal balance between estradiol and testosterone, leading to abnormal prostate cell proliferation[10].

According to the U.S. Department of Health and Human Services, social determinants of health (SDOH) are the conditions in the environment that affect a wide range of health, functioning, and quality-of-life outcomes and risks[9]. The social determinants of health include five main categories: economic stability, education, health care, neighborhood environment, and social context[9].

Relatively few studies have evaluated the use of endocrine disruptors and the relationship with socioeconomic status (SES). Preston et al. investigated the differences in personal care products (PCP) use by race/ethnicity and SES among 497 participants in the LIFECODES cohort, an ongoing pregnancy cohort of women who plan to deliver at Brigham and Women's Hospital in Boston, Massachusetts[13]. They found that women with lower SES (no college degree or other insurance) were likely to report higher use of individual product categories, including perfume, bar soap, lotion, and nail polish, compared to women with higher SES[13]. However, women with lower SES reported lower use of liquid soap and colored cosmetics than women with higher SES[13]. Asian women reported lower use of deodorant, hair gel, perfume, and nail polish during the first trimester compared to non-Hispanic White women[13].

Tyrrell et al. came to a different conclusion about the associations between socioeconomic status and environmental toxicant concentrations using data collected between

2001 and 2010 in a nationally representative sample of adults in the United States[15]. The study found that higher SES groups are not always protected from increased levels of environmental toxicants[15]. It was found that over a third of the associations observed involved increased risk of toxicant burdens for higher SES individuals[15]. For example, a higher burden of the polyfluorinated compounds (PFCs) was associated with higher SES[15]. PFCs may be associated with higher SES because they are found in expensive fabrics that are treated to provide water proofing[15].

The current literature has not investigated the association between phthalates and the social determinants of health. Therefore, I examined the National Health and Nutrition Examination Survey (NHANES) 2009-2018 data to determine if income, occupation, educational attainment, and marital status are associated with exposure to phthalates.

Methods

Data Source and Study Population

Data were obtained from the National Health and Nutrition Examination Survey (NHANES) to evaluate the association between social determinants of health and phthalate exposure. NHANES is a cross-sectional study that uses interviews and physical examinations to assess the health and nutritional status of non-institutionalized adults and children in the United States[4]. The NHANES interview includes demographic, socioeconomic, dietary, and health-related questions[4]. The examination component consists of medical, dental, and physiological measurements, and laboratory tests were administered by highly trained medical personnel[4]. NHANES examines a nationally representative sample of about 5,000 persons each

year from counties across the country[4]. The sampling methodology of NHANES is designed to yield results pertinent to the U.S. population.

The study included five survey cycles from 2009 to 2018. The study enrolled 32,285 adults between 2009 to 2018. Our analysis was limited to the adult population 18 years and older who had complete information on urinary phthalates concentrations at the time of recruitment. A total of 9,318 participants aged 18 and older had data for five urinary phthalates of interest.

Measurement of Exposures and Outcomes

Urinary phthalate metabolite concentrations were obtained from the NHANES laboratory Phthalates and Plasticizers Metabolites dataset. We decided to analyze mono carboxy-isononyl, mono carboxy-oxyoctyl, mono-2-ethyl-5-carboxypentyl, mono-n-butyl, and mono-benzyl because the NHANES data provided a substantial sample size. Spot urine samples were processed using enzymatic deconjugation of the glucuronidated phthalate monoesters followed by on-line solid phase extraction (SPE) coupled with reversed phase HPLC-ESI-MS/MS[3]. In addition, assay precision is improved by incorporating isotopically-labeled internal standards of the phthalate metabolites[3]. This selective method allows for rapid detection of monoester metabolites of commonly used phthalate diesters in human urine with limits of detection in the low ng/mL range[3].

Data for education, income, and marital status were obtained from the participant demographic questionnaire, and the occupation data was obtained from the participant occupation questionnaire.

Covariates

The covariates that were included in the model were ethnicity (white/black/Mexican), age (continuous), gender (male/female), and smoking status (never/some days/every day).

Statistical analyses

All data cleaning, descriptive and statistical analyses were performed using SAS 9.4 (SAS Institute, Cary, NC). The significance level was set as 0.05 for all hypothesis tests.

Histograms and normal probability plots checked for normality assumptions for each metabolite. In our analyses, urinary phthalates metabolite concentrations were log10-transformed because they were not normally distributed.

After controlling for important confounders, multiple linear regression models were used to evaluate the association between phthalate metabolites and income, education, and marital status. We did not include occupation because there was no category for unemployed individuals.

Linear models were fitted for each phthalate metabolite separately for the associations with income, marital status, and education level. Models included the appropriate survey weights to account for the stratified, multistage probability sampling method used to select NHANES participants. All results were reported as least square means with 95% confidence intervals (CI).

We also present results stratify by age because we observed a significant interaction by age for the association between the social determinants of health and the concentrations of the phthalates.

Results

Table 1 displays median (IQR) phthalate concentrations (ng/mL) by sample demographic characteristics. The final study population was composed of 9,318 U.S. adults aged 18 or older. Overall, 4632 (51%) participants were female, and 4586 (49%) participants were male. Among the population studied, 4479 (48%) of the sample ranged from 32-62 years old. Of the participants, 2598 (43%) were non-Hispanic white, 1707 (28%) were non-Hispanic Black, and 1754 (29%) were Mexican American and other Hispanic ethnicities. Among the sample, 1437 (39.3%) smoked every day, 382 (9.9%) smoked some days, and 2038 (52.8%) reported never smoking or were not smoking at the time of the survey.

Mono carboxy-isononyl phthalate association with social determinants of health

Initially, we intended to analyze the associations between the five phthalates with education, income, marital status, and occupation. Due to the inadequate sample size, we did not look at the association of occupation in our analyses.

Having greater educational attainment was associated with higher concentrations of mono carboxy-isononyl in crude models only. In the crude model, individuals who completed some college or an Associate's degree had higher mono carboxy-isononyl levels than individuals who did not complete high school (Table 2). In the adjusted model, the results were attenuated and were no longer significant.

Higher income participants had higher levels of mono carboxy-isononyl. After adjusting for sex, age, race, and smoking status, individuals with an income between $55,000 and $74,999 had significantly higher levels of mono carboxy-isononyl compared to individuals with

an income less than $20,000. In the age-stratified models, in the middle age category, 32 to 62 years, those with higher incomes had higher levels of mono carboxy-isononyl (Table 3).

In both the crude and adjusted models, individuals who were never married had lower levels of mono carboxy-isononyl compared to those married or living with a partner. In the stratified model, individuals 62 years and older and never married had lower levels of mono carboxy-isononyl compared to those that are married or living with a partner. There were no differences observed in the other two age categories.

Mono carboxy-oxyoctyl phthalate association with social determinants of health

In the crude model, individuals that have completed some college or an Associate's degree had higher levels of mono carboxy-oxyoctyl compared to individuals that did not complete high school. These results were attenuated in the adjusted models and results were no longer significant.

In both crude and adjusted models, higher income status was positively associated with mono carboxy-oxyoctyl. From the crude models, individuals in the two highest income categories had higher mono carboxy-oxyoctyl concentrations compared to individuals with an income less than $20,000. After adjusting for important confounders, the two highest income categories remained significant.

In both the crude and adjusted models, marital status was associated with mono carboxy-oxyoctyl concentrations with the lowest levels observed among never married individuals compared to those in either of the other two groups. In our stratified analyses, among individuals 18 to 32 years old, those who were never married had higher mono carboxy-oxyoctyl concentration levels compared those who were married. Conversely, among

individuals 62 years or older, those who were never married had lower concentrations of mono carboxy-oxyoctyl compared to those who were married.

Mono-2-ethyl-5-carboxypentyl phthalate (MECP) association with social determinants of health

In both the crude and adjusted models, individuals with higher educational status had lower levels of mono-2-ethyl-5-carboxypentyl compared to individuals that did not complete high school. In the age-stratified model, among the individuals 18 to 32 years and 62 years or older, those who were college graduates had lower levels of mono-2-ethyl-5-carboxypentyl compared to individuals that did not complete high school.

In both the crude and adjusted models, higher income was inversely associated with MECP compared to individuals with an income less than $20,000.

In the adjusted model, individuals who had never been married had lower concentrations of MECP compared those who were married or divorced. In the stratified model, among the three age categories, the concentration levels of MECP did not differ by the marital status categories.

Mono-n-butyl phthalate association with social determinants of health

In both the crude and adjusted models, higher educational attainment was inversely associated with lower concentration levels of mono-n-butyl compared to individuals that did not complete high school. In the stratified model, among the three age categories, those who were college graduates had lower levels of mono-n-butyl compared to individuals that did not complete high school.

From the crude models, higher income status was positively associated with levels of mono-n-butyl compared to individuals with an income less than $20,000. After adjusting for

important confounders, the positive association between income and mono-n-butyl was strengthened.

In the crude model, individuals who were never married and widowed, divorced or separated had significantly lower levels of mono-n-butyl compared to individuals who were married or living with a partner. After adjustment for confounders the results were attenuated and no longer significant.

Mono-benzyl phthalate association with social determinants of health

In the crude and adjusted models, individuals that were a college graduate or had a higher degree had lower levels of mono benzyl compared to individuals that did not complete high school. In the stratified model, among the three age categories, those who were college graduates had significantly lower levels of mono-benzyl compared to individuals that did not complete high school.

In crude and adjusted analyses, compared with lower income participants, those with higher income tended to have significantly lower concentrations of mono-benzyl. In the stratified analysis, among the three age categories, those with higher incomes had significantly lower levels of mono-benzyl.

In both the crude and adjusted models, individuals who were never married had higher levels of mono-benzyl compared to individuals that were married or living with a partner.

Discussion

Our results for the analysis between income and the phthalates are consistent with prior studies. We found that mono carboxy-isononyl and mono carboxy- oxyoctyl were positively associated with income status. However, mono-2-ethyl-5-carboxypentyl, mono-n-

butyl, and mono-benzyl were inversely associated with income. A cross-sectional study used 2001-2010 NHANES data to analyze the association between 179 urinary heavy metals and phthalates and poverty income ratio (PIR)[15]. Tyrell et al. found that nine chemicals, including mono carboxyoctyl were positively associated with PIR[15]. However, mono-benzyl and mono-n-butyl were inversely associated with PIR[15]. Also, we found that mono-n-butyl and mono-benzyl were inversely associated with educational attainment. Additionally, we found that mono carboxy- isononyl, mono carboxy-octyl, MECP, and mono-benzyl were associated with being single or never being married. No previous studies have examined the association between phthalates and education attainment and marital status in the adult population.

Among two of the high molecular weight phthalates, mono carboxy-isononyl and mono carboxy-oxyoctyl were positively associated with income. The association we observed between the phthalates concentration levels and income could be because the phthalates are found in furniture, vinyl flooring, and automobile upholstery. Therefore, individuals with higher incomes may be able to afford new items that are made with the phthalates. Similarly, for mono carboxy-isononyl and mono carboxy-oxyoctyl, individuals that were married had higher levels. In our data, 34% of married individuals have incomes $75,000 or greater compared to 18% individuals that were never married. This suggests that individuals that are married have higher incomes and may be more likely to purchase new furniture, flooring and automobiles.

The low molecular weight phthalates, mono-n-butyl and mono-benzyl were inversely associated with income. Low molecular weight phthalates are found in personal care products such as shampoo, deodorant, and fragrances. A potential mechanism for this association is that

less expensive personal care products are packaged in plastic which are created using phthalates whereas more expensive products use other types of packaging.

After stratifying by age, we noticed a common trend that the phthalate levels decreased with age. A potential mechanism is that newer products contain phthalates and are more likely to be used by younger individuals.

A strength of our study is that it included five survey cycles from 2009 to 2018 for a total of 9318 participants. The large sample size improved the study power. A limitation is the cross-sectional design of NHANES which allows for an examination of exposure/outcome associations; however, causal inferences are not possible[14]. Another limitation is that phthalates have short biologic half-lives […] and are quickly excreted from the body[12]. The NHANES study uses urine samples which may or may not reflect an individual's long-term exposure level[12]. Another limitation is that we could not analyze the association between phthalates and occupation. The NHANES occupation variable did not include unemployed individuals, and almost half of the participants were missing data (n=4174). Therefore, future studies should examine the association between phthalates and other social determinants of health, such as occupation.

Conclusion

In summary, in this national representative sample of US adults, we observed significant positive associations between income and mono carboxy-isononyl and mono carboxy-oxyoctyl. In contrast, we observed inverse associations between income and mono-2-ethyl-5-carboxypentyl, mono-n-butyl and mono-benzyl. Research surrounding phthalates is essential because phthalates may be harmful and can lead to potentially serious health conditions.

Further research is needed to determine other potential associations between phthalates and the social determinants of health.

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Tables and Figures

Figure 1. Phthalates, metabolites, low molecular weight (LMW) or high molecular weight (HMW), sources of exposure, level of detection, and half-life.

Phthalate (abbreviation)	Metabolites	LMW or HMW	Sources of exposure (Kim & Park, 2014)	Level of Detection (ng/mL) - 2017/2018 values	Half-life (in Air)
Di-isodecyl phthalate (DDP)	Mono(carboxy-isononyl) phthalate (MCNP)	HMW	Household products (toys, coated fabrics, vinyl flooring, wall coverings, lamination film, wire and cable insulation, footwear, paints, adhesives, lacquers), school supplies (scented erasers and pencil case)	0.2	0.6 days
Di-isononyl phthalate (DNP)	Mono(carboxy-isoctyl) phthalate (MCOP)	HMW	Household products (toys, floor tiles, wall coverings, furniture, paints, adhesives, gloves, lacquers), clothes and footwear, car interiors, food packaging, medical devices	0.3	0.7 days
Di(2-ethylhexyl) phthalate (DEHP)	Mono-2-ethyl-5-carboxypentyl phthalate (MECPP)	HMW	Household products (toys, floor tiles, wall coverings, furniture, paints, adhesives, gloves, shower curtains), rainwear, automobile upholstery, packaging film and sheets, shoes, dust, food packaging, medical devices	0.4	12 hours
Di-n-butyl phthalate (DBP)	Mono-n-butyl phthalate (MBP)	LMW	Paints, adhesives, personal care products (perfumes, aftershaves, nail care, makeup), excipient in pharmaceuticals and supplements	0.4	7.4 hours to 3.1 days
Benzylbutyl phthalate (BzBP)	Mono-benzyl phthalate (MBzP)	LMW	Paint, adhesives, car care products, toys, food packaging, furniture upholstery, vinyl and carpet tiles, synthetic leather, deodorants	0.3	1.5 days

Note: Adapted from "Phthalate exposure and childhood obesity," by Kim, S. H., & Park, M. J., 2014, Annals of pediatric endocrinology & metabolism, 19(2), p.70 (https://doi.org/10.6065/apem.2014.19.2.69). Copyright 2014 Annals of Pediatric Endocrinology & Metabolism

Table 1. Frequency distribution and phthalate concentrations (ng/mL) in a sample of individuals 18 and older (n=9318).

Characteristics	Frequency n, %	Mono carboxy-isononyl phthalate Median, IQR	Mono carboxy-oxyoctyl phthalate Median, IQR	Mono-2-ethyl-5-carboxypentyl phthalate Median, IQR	Mono-n-butyl phthalate Median, IQR	Mono-benzyl phthalate Median, IQR
Overall	9318 (100%)	1.9 (1.0-3.9)	9.5 (4.0-27.2)	11.5 (5.8-22.4)	11.5 (5.4-21.9)	4.3 (1.8-10.3)
Gender						
Male	4586 (49.2%)	2.1 (1.1-4.3)	9.9 (4.2-28.8)	11.8 (6.2-22.8)	11.3 (5.6-21.3)	4.4 (2.0-10.0)
Female	4732 (50.8%)	1.8 (0.9-3.7)	8.9 (3.8-25.8)	11.1 (5.4-22.1)	11.6 (5.2-22.8)	4.2 (1.6-10.5)
Age						
18-32 y	2321 (24.9%)	2.3 (1.2-4.8)	12.0 (4.9-39.3)	12.4 (6.1-25.1)	12.9 (6.0-24.7)	5.9 (2.3-14.5)
32-62 y	4479 (48.1%)	1.9 (0.9-3.9)	9.3 (3.8-27.1)	11.2 (5.5-21.7)	11.0 (5.1-21.0)	4.0 (1.7-9.3)
62 y	2518 (27.0%)	1.8 (0.9-3.3)	8.2 (3.8-20.9)	11.2 (6.0-21.8)	11.2 (5.5-21.2)	3.7 (1.6-8.6)
Race/Ethnicity						
Mexican American and Other Hispanic	1754 (29.0%)	1.7 (0.9-3.2)	9.5 (4.2-25.7)	10.7 (5.8-20.9)	10.3 (5.0-19.1)	3.1 (1.4-7.3)
Non-Hispanic White (ref)	2598 (42.9%)	2.0 (1.0-3.8)	9.4 (4.0-28.2)	9.3 (4.7-17.2)	9.2 (4.1-17.1)	4.0 (1.7-9.8)
Non-Hispanic Black	1707 (28.2%)	2.1 (1.1-4.4)	10.7 (4.6-30.9)	11.1 (5.8-20.1)	13.5 (6.8-25.4)	5.4 (2.4-12.3)
Missing	2022					
Education Level						

	Less than a high graduate	2292 (24.6%)	1.9 (1.0-3.7)	9.2 (4.1-23.4)	13.1 (6.6-26.0)	12.6 (6.1-24.9)	4.9 (2.1-11.7)
	High school graduate/GED or equivalent	2141 (23.0%)	1.9 (1.0-3.8)	9.1 (3.9-25.2)	11.5 (5.7-22.3)	11.9 (5.6-22.9)	4.6 (2.0-11.5)
	Some college or AA degree	2771 (29.8%)	2.1 (1.0-4.2)	9.7 (4.1-31.2)	11.2 (5.8-21.8)	11.5 (5.4-21.4)	4.7 (1.9-10.8)
	College graduate or above	2097 (22.6%)	1.9 (0.9-4.0)	9.6 (3.9-30.8)	10.2 (5.0-19.6)	9.9 (4.4-19.8)	3.0 (1.3-6.8)
	Missing	4					
Occupational Status							
	Private employment	3833 (75.2%)	2.1 (1.1-4.4)	11.00 (4.5-34.9)	11.4 (5.7-22.4)	11.1 (5.2-21.6)	4.4 (1.7-9.7)
	A government employee	753 (14.8%)	1.9 (1.0-4.0)	9.6 (3.9-28.4)	10.8 (5.1-20.6)	10.4 (5.2-20.5)	4.0 (2.0-9.5)
	Self-employment	513 (10.1%)	2.2 (1.1-4.4)	9.6 (4.0-24.8)	12.3 (6.0-23.5)	11.2 (5.8-21.1)	3.8 (1.7-9.0)
	Missing	4174					
Marital Status							
	Married and living with partner	5189 (58.9%)	1.9 (1.0-3.7)	9.0 (4.0-26.0)	11.3 (5.7-21.9)	10.8 (5.1-20.9)	3.9 (1.6-8.8)
	Widowed, divorced, separated	1926 (21.8%)	1.8 (0.9-3.6)	8.6 (3.7-23.6)	11.6 (5.8-22.5)	11.8 (5.7-21.8)	4.4 (1.9-10.9)
	Never married	1702 (19.3%)	2.2 (1.1-4.7)	11.2 (4.4-33.9)	11.5 (5.7-22.7)	12.8 (5.6-24.5)	5.0 (2.2-13.4)
	Missing	495					
Annual Family Income							

	Under $20,000	2214 (26.1%)	1.9 (0.9-3.9)	9.0 (3.9-25.2)	12.7 (6.3-24.8)	13.2 (6.1-25.3)	5.9 (2.4-14.4)
	$20,000 to $34,999	1685 (19.9%)	2.0 (1.1-3.9)	9.7 (4.2-23.5)	11.8 (6.1-23.2)	12.0 (5.7-23.0)	5.0 (2.2-11.3)
	$35,000 to $54,999	1544 (18.2%)	2.0 (1.0-3.9)	9.9 (4.2-28.9)	11.7 (6.0-21.3)	11.8 (5.5-21.5)	4.2 (1.8-10.1)
	$55,000 to $74,999	863 (10.2%)	1.9 (1.0-3.7)	9.4 (4.0-24.9)	9.8 (5.5-20.6)	10.0 (4.5-19.5)	3.7 (1.6-8.7)
	$75,000 to $99,999	773 (9.1%)	2.1 (1.0-4.1)	10.9 (4.2-34.6)	11.0 (5.7-21.8)	10.2 (5.3-19.8)	4.0 (1.5-7.9)
	$100,000 and over	1405 (16.6%)	2.0 (1.0-4.5)	10.3 (4.0-35.4)	10.3 (4.9-19.9)	9.5 (4.3-18.6)	2.9 (1.2-6.4)
	Missing	156					
Smoking Status							
	Every day	1437 (37.3%)	2.0 (1.0-3.8)	8.6 (3.8-22.6)	11.4 (5.5-22.6)	12.2 (5.5-24.2)	5.8 (2.4-13.2)
	Some days	382 (9.9%)	2.0 (1.1-4.1)	9.4 (3.9-33.5)	12.2 (5.8-23.8)	12.1 (6.1-22.8)	5.5 (2.3-12.4)
	No	2038 (52.8%)	2.0 (1.0-3.8)	9.2 (4.2-25.1)	11.3 (6.1-22.4)	10.9 (5.5-20.6)	4.0 (1.7-9.0)
	Missing	5461					

Table 2. Adjusted Models using Multiple Linear Regression (N = 9318). Reported as Least Square Means and 95% confidence intervals

	Mono carboxy-isononyl phthalate	Mono carboxy-oxyoctyl phthalate	Mono-2-ethyl-5-carboxypentyl phthalate	Mono-n-butyl phthalate	Mono-benzyl phthalate
Education Level					
Less than a high graduate	0.64 (0.56,0.72)	2.42 (2.31,2.53)	2.38 (2.30,2.46)	2.34 (2.25,2.44)	1.64 (1.54,1.74)
High school graduate/GED or equivalent	0.58 (0.50,0.67)	2.27 (2.16, 2.39)	2.26 (2.17,2.34)	2.21 (2.12,2.31)	1.43 (1.33,1.53)
Some college or AA degree	0.57 (0.49, 0.65)	2.31 (2.20,2.41)	2.23 (2.16,2.31)	2.27 (2.18,2.36)	1.42 (1.33,1.52)
College graduate or above	0.69 (0.57,0.81)	2.49 (2.33,2.65)	2.27 (2.15,2.39)	2.19 (2.06,2.33)*	1.11 (0.97,1.26)*
Marital Status					
Married and living with partner	0.62 (0.55,0.68)	2.35 (2.26,2.44)	2.29 (2.22,2.35)	2.24 (2.16, 2.32)	1.39 (1.30,1.47)
Widowed, divorced, separated	0.61 (0.51,0.71)	2.31 (2.18,2.44)	2.29 (2.20,2.39)	2.30 (2.20,2.40)	1.56 (1.45,1.67)*
Never married	0.47 (0.34,0.60)*	2.21 (2.04,2.37)*	2.18 (2.05,2.30)*	2.29 (2.17,2.42)	1.49 (1.36,1.62)
Annual Family Income					
Under $20,000	0.53 (0.45,0.62)	2.25 (2.14,2.36)	2.37 (2.29,2.45)	2.39 (2.29,2.49)	1.66 (1.56,1.76)
$20,000 to $34,999	0.65 (0.55,0.74)	2.38 (2.25,2.50)	2.32 (2.23,2.42)	2.28 (2.16,2.40)	1.55 (1.43,1.66)
$35,000 to $54,999	0.71 (0.60,0.81)	2.46 (2.33,2.60)*	2.25 (2.15,2.35)*	2.28 (2.17,2.38)	1.40 (1.28,1.52)
$55,000 to $74,999	0.52 (0.37,0.66)*	2.29 (2.10,2.47)	2.16 (2.02,2.30)*	1.99 (1.82,2.15)*	1.24 (1.07,1.42)
$75,000 to $99,999	0.71 (0.54,0.88)	2.64 (2.42,2.86)*	2.35 (2.19,2.51)*	2.27 (2.08,2.46)	1.26 (1.05,1.46)
$100,000 and over	0.75 (0.62,0.89)	2.58 (2.40,2.75)*	2.26 (2.13,2.40)*	2.17 (2.02,2.33)*	1.07 (0.90,1.23)*

Note: All models are adjusted for gender, age, race, and smoking status

*p<0.05.

Table 3. Stratified analysis by age. Reported as Least Square Means and 95% confidence interval.

	Age		
	18-32 years old	32-62 years old	62+ years old
Mono carboxy-isononyl phthalate			
Income			
Under $20,000	0.92 (0.74,1.10)	0.46 (033,0.59)	0.47 (0.32,0.62)
$20,000 to $34,999	0.78 (0.55,1.02)	0.62 (0.47,0.76)	0.65 (0.50,0.80)
$35,000 to $54,999	0.81 (0.58,1.04)	0.72 (0.57,0.87)	0.68 (0.49,0.87)
$55,000 to $74,999	0.27 (0.04,0.50)	0.57 (0.35,0.80)	0.59 (0.37,0.81)
$75,000 to $99,999	0.70 (0.21,1.19)	0.91 (0.68,1.14)	0.48 (0.22,0.74)
$100,000 and over	1.03 (0.68,1.38)	0.74 (0.53,0.95)	0.69 (0.45,0.93)
Marital Status			
Married and living with partner	0.71 (0.54,0.88)	0.64 (0.54,0.73)	0.56 (0.43,0.69)
Widowed, divorced, separated	1.49 (0.95,2.02)	0.52 (0.38,0.66)	0.55 (0.42,0.68)
Never married	0.82 (0.66,0.97)	0.60 (0.42,0.77)	0.41 (0.16,0.66)
Mono carboxy-oxyoctyl phthalate			
Marital Status			
Married and living with partner	2.52 (2.29,2.75)	2.34 (2.21,2.47)	2.22 (2.05,2.40)
Widowed, divorced, separated	2.55 (2.06,3.04)	2.26 (2.08,2.44)	2.26 (2.10,2.43)
Never married	2.70 (2.48,2.93)	2.35 (2.13,2.57)	2.00 (1.65,2.34)
Mono-2-ethyl-5-carboxypentyl phthalate			
Education			
Less than a high graduate	2.53 (2.33,2.73)	2.22 (2.09,2.35)	2.48 (2.34,2.62)
High school graduate/GED or equivalent	2.57 (2.38,2.76)	2.15 (2.02,2.28)	2.24 (2.08,2.39)
Some college or AA degree	2.41 (2.23,2.59)	2.18 (2.07,2.29)	2.21 (2.06,2.36)
College graduate or above	2.24 (1.91,2.57)	2.23 (2.07,2.38)	2.34 (2.15,2.53)
Marital Status			
Married and living with partner	2.49 (2.32,2.65)	2.19 (2.10,2.29)	2.29 (2.16,2.42)
Widowed, divorced, separated	2.78 (2.30, 3.26)	2.19 (2.06,2.32)	2.37 (2.24,2.50)
Never married	2.45 (2.28,2.61)	2.18 (2.03,2.33)	2.24 (1.98,2.50)

Mono-n-butyl phthalate			
Education			
Less than a high graduate	2.52 (2.30,2.74)	2.28 (2.14,2.43)	2.32 (2.15,2.50)
High school graduate/GED or equivalent	2.56 (2.34,2.77)	2.10 (1.96,2.24)*	2.20 (2.03,2.38)
Some college or AA degree	2.39 (2.19,2.60)	2.25 (2.13,2.36)	2.26 (2.08,2.44)
College graduate or above	2.17 (1.74,2.61)	2.15 (1.94,2.35)	2.29 (2.05,2.53)
Mono-benzyl phthalate			
Education			
Less than a high graduate	2.10 (1.86,2.35)	1.59 (1.44,1.74)	1.47 (1.28,1.65)
High school graduate/GED or equivalent	2.05 (1.83,2.28)	1.36 (1.22, 1.51)*	1.25 (1.06,1.45)
Some college or AA degree	1.76 (1.54,1.98)*	1.44 (1.31,1.57)	1.26 (1.06,1.45)*
College graduate or above	1.23 (0.78,1.68)*	1.10 (0.92,1.29)*	1.08 (0.84,1.33)*
Income			
Under $20,000	1.94 (1.70,2.17)	1.59 (1.44,1.74)	1.60 (1.42,1.79)
$20,000 to $34,999	1.87(1.61,2.14)	1.50 (1.34,1.67)	1.44 (1.22,1.65)
$35,000 to $54,999	2.07 (1.79,2.34)	1.40 (1.22,1.59)	1.07 (0.85,1.30)*
$55,000 to $74,999	1.80 (1.32,2.27)	1.30 (1.07,1.54)	0.91 (0.63,1.20)*
$75,000 to $99,999	1.69 (0.90,2.48)	1.34 (1.09,1.59)	0.99 (0.64,1.35)*
$100,000 and over	1.42 (1.04,1.79)*	0.97 (0.75,1.20)*	1.07 (0.78,1.35)*

Note: All models are adjusted for gender, age, race, and smoking status

*p<0.05.