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BRIEF REPORT

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Pre-pregnancy dietary arsenic consumption among women in the United States

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Abstract

Background: Arsenic is associated with several adverse health outcomes, including some birth defects. Although diet is the predominant route of arsenic exposure in the United States (U.S.), limited data exist regarding pre-pregnancy dietary arsenic consumption among U.S. women.

Methods: Using data collected in the National Birth Defects Prevention Study (NBDPS), we estimated daily dietary arsenic consumption during the year before pregnancy for 10,886 mothers of nonmalformed control children delivered from 1997–2011. Responses to the NBDPS dietary assessment and food item estimates of total and inorganic arsenic were used to estimate consumption. Associations between total and inorganic arsenic consumption and selected maternal characteristics were estimated using multinomial logistic regression.

Results: Estimates of mean maternal total and inorganic dietary arsenic consumption were 14.9 and 5.2 μg/day, respectively. Several positive and inverse associations with confidence intervals that excluded the null were observed. Comparing mothers in the middle or high total arsenic consumption tertiles to those in the low tertile, we observed positive associations (odds ratios = 1.3–3.8) for maternal age (≥30 years), lower (0–8 years) or higher (>12 years) education, race/ethnicity (non-Hispanic Black, Hispanic, other), and early pregnancy drinking with no binge episodes, and inverse associations (odds ratios = 0.4–0.8) for age (<25 years), body mass index (≥30.0 kg/m^2), and early pregnancy smoking. Findings tended to be similar for inorganic arsenic consumption.

Conclusions: These contemporary estimates of pre-pregnancy dietary arsenic consumption among U.S. women show associations between both total and inorganic dietary arsenic consumption and several maternal characteristics, improving characterization of the public health impact of this exposure.

KEYWORDS
arsenic, birth defects, diet, population-based, pregnancy

1 | INTRODUCTION

Arsenic is a naturally occurring element present in both inorganic and organic species. Inorganic arsenic is recognized as a greater threat to human health than organic arsenic (Hughes, Beck, Chen, Lewis, & Thomas, 2011) as evidenced by reports of positive associations with adverse health outcomes (reviewed in Abdul, Jayasinghe, Chandana, Jayasumana, & De Silva, 2015), including some birth defects (Jin et al., 2016). Most studies examined drinking water exposure. With low arsenic concentrations in finished drinking water throughout much of the United States (U.S.), however, diet is the predominant source of arsenic exposure (Kurzius-Spencer et al., 2014; Xue, Zartarian, Wang, Liu, & Georgopoulos, 2010). Currently, no consensus guidelines exist for tolerable dietary arsenic intake.

Inorganic arsenic contamination is found in rice, grains, vegetables, and fruits (reviewed in Agency for Toxic Substances and Disease Registry, 2007); organic arsenic contamination is found in shellfish (reviewed in Agency for Toxic Substances and Disease Registry, 2007). Contamination varies depending on water and soil composition (Yan-Chu, 1994) and can be affected by previous arsenical pesticide use (reviewed in Agency for Toxic Substances and Disease Registry, 2007). Despite diet being an important route of exposure and associations suggested between arsenic and birth defects, only one study with rather contemporary data (2006–2008) was identified that examined dietary arsenic consumption among U.S. reproductive-aged women. Using total arsenic (all forms) estimates from the U.S. Food and Drug Administration Total Diet Study (TDS) and median food consumption levels for different age–sex groups, investigators estimated dietary arsenic consumption among reproductive-aged women at approximately 0.16 μg/kg-body weight (bw)/day for total arsenic; applying various ratios of organic to inorganic arsenic in foods, estimates of inorganic arsenic consumption ranged from 0.03–0.08 μg/kg-bw/day (Jara & Winter, 2014).

Recently, we analyzed data collected in Iowa for the National Birth Defects Prevention Study (NBDPS) to investigate associations between multisource maternal arsenic exposure, including pre-pregnancy dietary arsenic consumption, and orofacial clefts in offspring (Suhl et al., 2018). We observed values for mothers of nonmalformed controls for total (0.16 μg/kg-bw/day) and inorganic (0.07 μg/kg-bw/day) arsenic similar to those reported previously (Jara & Winter, 2014). The NBDPS is the largest U.S. population-based case–control study of birth defects and enrolled children from 10 sites with estimated dates of delivery (EDDs) from 1997–2011 (Reefhuis et al., 2015). Mothers of control children who participated in the NBDPS were observed to be representative on several characteristics of U.S. mothers who delivered a liveborn child (Cogswell et al., 2009).

Building on our Iowa study, we analyzed data for all NBDPS control mothers to estimate their dietary arsenic consumption during the year before pregnancy and associations with selected characteristics. Our findings provide additional insights into maternal pre-pregnancy dietary arsenic consumption to better characterize the public health impact of this exposure.

2 | MATERIALS AND METHODS

2.1 | Study sample

NBDPS methods are detailed elsewhere (Reefhuis et al., 2015). NBDPS control children were a random sample of nonmalformed livebirths selected from hospital delivery logs or birth certificate files and delivered during the same timeframe and geographic catchment areas as case children. We restricted analyses to data reported by NBPDS control mothers as they may be more representative of the underlying distribution of pre-pregnancy dietary arsenic consumption among the general U.S. population than case mothers. The NBDPS protocol was approved by the institutional review board at the Centers for Disease Control and Prevention and each NBDPS site.

2.2 | Exposure assessment

NBDPS data collection included a telephone interview with case and control mothers administered 6 weeks to 24 months after their EDDs. The interview included a 58-item food frequency questionnaire (FFQ) adapted from the Willett FFQ (Willett, Reynolds, Cottrell-Hoehner, Sampson, & Browne, 1987) to assess diet for the year before pregnancy. Dietary arsenic exposure methods are detailed elsewhere (Suhl et al., 2018). Briefly, each FFQ item was linked to all corresponding items in the TDS 1991–2005 (U.S. Food and Drug Administration, 2007) and 2006–2013 (U.S. Food and Drug Administration, 2017), and mean total arsenic concentrations were estimated for each FFQ item. The TDS assumes estimates below the limit of detection to be 0 μg/g; therefore, all such estimates were assumed to be 0 μg/g in our study. Because the NBDPS collected consumption estimates for the year before pregnancy, to retain the same TDS estimates for mothers with EDDs within the same calendar year, those with EDDs in 2006 were linked to 1991–2005 estimates, and those with EDDs in 2007

TABLE 1 Unadjusted associations between selected characteristics and total dietary arsenic consumption among National Birth Defects Prevention Study control mothers, 1997–2011

	Total arsenic (μg/day)							
	Low (<4.5) (N = 3,629)		Medium (4.5–15.4) (N = 3,629)		High (≥15.4) (N = 3,628)		Medium versus low	High versus low
Maternal characteristic	N	%	N	%	N	%	OR (95% CI)	OR (95% CI)
Age (years)[a]								
<20	507	14.0	306	8.4	222	6.1	0.6 (0.5, 0.7)	0.4 (0.4, 0.5)
20–24	1,034	28.5	736	20.3	646	17.8	0.7 (0.6, 0.8)	0.6 (0.6, 0.7)
25–29	1,005	27.7	1,057	29.1	991	27.3	Referent	Referent
30–34	761	21.0	1,002	27.6	1,072	29.6	1.3 (1.1, 1.4)	1.4 (1.3, 1.6)
35–39	261	7.2	455	12.5	575	15.9	1.7 (1.4, 2.0)	2.2 (1.9, 2.6)
≥40	61	1.7	73	2.0	122	3.4	1.1 (0.8, 1.6)	2.0 (1.5, 2.8)
Education (years)[a]								
0–8	160	4.4	178	4.9	200	5.6	1.4 (1.1, 1.8)	1.6 (1.3, 2.1)
9–11	506	14.1	360	10	363	10.1	0.9 (0.8, 1.1)	0.9 (0.8, 1.1)
12	999	27.8	773	21.5	760	21.1	Referent	Referent
13–15	983	27.3	992	27.5	936	26	1.3 (1.1, 1.5)	1.3 (1.1, 1.4)
≥16	952	26.4	1,301	36.1	1,344	37.3	1.8 (1.6, 2.0)	1.9 (1.6, 2.1)
Race/ethnicity								
Non-Hispanic White	2,399	66.1	2,161	59.6	1,854	51.1	Referent	Referent
Non-Hispanic Black	201	5.5	362	10.0	591	16.3	2.0 (1.7, 2.4)	3.8 (3.2, 4.5)
Hispanic	837	23.1	881	24.3	895	24.7	1.2 (1.0, 1.3)	1.4 (1.2, 1.6)
Other	191	5.3	224	6.2	286	7.9	1.3 (1.1, 1.6)	1.9 (1.6, 2.4)
Pre-pregnancy BMI (kg/m^2)								
<18.5	202	5.8	189	5.4	165	4.8	0.9 (0.7, 1.1)	0.8 (0.6, 1.0)
18.5–24.9	1,794	51.3	1,889	54.1	1,912	55.3	Referent	Referent
25–30.0	811	23.2	784	22.4	795	23.0	0.9 (0.8, 1.0)	0.9 (0.8, 1.0)
≥30.0	688	19.7	633	18.1	584	16.9	0.9 (0.8, 1.0)	0.8 (0.7, 0.9)
NBDPS site								
Arkansas	495	13.6	507	14.0	394	10.9	1.3 (1.1, 1.5)	1.4 (1.2, 1.7)
California	437	12.0	384	10.6	373	10.3	1.1 (0.9, 1.3)	1.5 (1.2, 1.8)
Georgia	214	5.9	347	9.6	500	13.8	2.0 (1.6, 2.5)	4.1 (3.3, 5.1)
Iowa	514	14.2	418	11.5	290	8.0	Referent	Referent
Massachusetts	318	8.8	409	11.3	553	15.2	1.6 (1.3, 1.9)	3.1 (2.5, 3.8)
New Jersey	112	3.1	165	4.6	277	7.6	1.8 (1.4, 2.4)	4.4 (3.4, 5.7)
New York	314	8.7	289	8.0	337	9.3	1.1 (0.9, 1.4)	1.9 (1.5, 2.3)
North Carolina	322	8.9	339	9.3	280	7.7	1.3 (1.1, 1.6)	1.5 (1.2, 1.9)
Texas	421	11.6	410	11.3	407	11.2	1.2 (1.0, 1.4)	1.7 (1.4, 2.1)
Utah	482	13.3	361	10.0	217	6.0	0.9 (0.8, 1.1)	0.8 (0.6, 1.0)
Alcohol use[b,c]								
No drinking	2,357	65.8	2,188	61.1	2,234	62.1	Referent	Referent
Drinking with no binge episodes	730	20.4	951	26.7	957	26.6	1.4 (1.3, 1.6)	1.4 (1.2, 1.5)
Drinking and ≥1 binge episode	496	13.8	443	12.4	408	11.3	1.0 (0.8, 1.1)	0.9 (0.8, 1.0)

(Continues)

TABLE 1 (Continued)

Maternal characteristic	Total arsenic (μg/day) Low (<4.5) (*N* = 3,629) *N*	%	Medium (4.5–15.4) (*N* = 3,629) *N*	%	High (≥15.4) (*N* = 3,628) *N*	%	Medium versus low OR (95% CI)	High versus low OR (95% CI)
Cigarette smoke exposure[b]								
No active or passive smoking	2,336	64.9	2,550	71.0	2,637	73.0	Referent	Referent
Active smoking only	330	9.2	258	7.2	231	6.4	0.7 (0.6, 0.9)	0.6 (0.5, 0.7)
Passive smoking only	450	12.5	445	12.4	445	12.3	0.9 (0.8, 1.0)	0.9 (0.8, 1.0)
Active and passive smoking	484	13.4	341	9.5	299	8.3	0.7 (0.6, 0.8)	0.6 (0.5, 0.6)

Abbreviations: BMI, body mass index; CI, confidence interval; NBDPS, National Birth Defects Prevention Study; OR, odds ratio.
[a]At delivery.
[b]During the period one month before conception through the third month of pregnancy.
[c]Binge drinking defined as 4 or more drinks in one sitting.

were linked to 2006–2013 estimates. For each mother who completed the FFQ, grams consumed of each FFQ item/day was estimated using their reported number of servings consumed/day and the item's grams/serving, as reported in the U.S. Department of Agriculture Food Composition Database (U.S. Department of Agriculture, 2016). Grams consumed of each FFQ item/day were multiplied by the corresponding TDS mean arsenic concentration estimates to obtain the amount of arsenic consumed per FFQ item/day (μg/day). Total arsenic consumption (μg/day) was estimated by summing across all FFQ items. Inorganic arsenic consumption was estimated using the same approach but applying estimates reported in Schoof et al. (1999). Using maternal reported pre-pregnancy weight, we estimated μg/kg-bw/day for total and inorganic arsenic for comparison with previously reported estimates. Of the 58 FFQ items, TDS estimates for total arsenic were available for 55 items, and inorganic arsenic estimates were available for 24 items.

2.3 | Statistical analysis

We estimated mean, median, *SD*, and tertiles of exposure (in μg/day and μg/kg-bw/day) for maternal pre-pregnancy total and inorganic dietary arsenic consumption. Mothers who reported total energy intakes of <500 or >5,000 calories/day were excluded from analyses. Crude odds ratios and 95% confidence intervals were estimated using multinomial logistic regression to identify associations between selected maternal characteristics and total and inorganic dietary arsenic consumption; the lowest tertile of consumption was used as the comparator outcome category. Characteristics examined were maternal age and education at delivery, race/ethnicity, pre-pregnancy body mass index, NBDPS site, and early pregnancy (one month before through the third month of pregnancy) alcohol use and cigarette smoke exposure. We examined dietary arsenic exposure independent of drinking water exposure due to challenges we encountered in linking maternal residence to water arsenic measurements in our Iowa study, the generally low arsenic concentrations in U.S. finished drinking water, and the low proportion (8%) of NBDPS mothers that reported using well water. Analyses were conducted using SAS v. 9.4 (SAS Institute Inc., 2013).

3 | RESULTS

Overall, 11,829 control mothers participated in the NBDPS with 11,157 providing responses to each FFQ item. Of these 11,157 mothers, 271 consumed <500 or >5,000 calories/day and were excluded from analyses, leaving 10,886 mothers. Using FFQ data reported by these 10,886 mothers, we estimated mean maternal pre-pregnancy total dietary arsenic consumption per day at 14.9 μg/day (*SD* = 22.4; median = 8.2; range = 0.1–699.4; tertiles: low = <4.5, middle = 4.5–15.4, high = ≥15.4 μg/day) and inorganic dietary arsenic consumption at 5.2 μg/day (*SD* = 4.0; median = 4.2; range = 0.1–55.3; tertiles: low = <3.2, middle = 3.2–5.5, high = ≥5.5 μg/day). The respective estimates for mean total and inorganic dietary arsenic consumption in μg/kg-bw/day were 0.23 and 0.08.

We observed several positive and inverse associations between selected maternal characteristics and total dietary arsenic consumption, for which most confidence intervals excluded the null. Mothers in the middle and high tertiles, compared to those in the low tertile, were

TABLE 2 Unadjusted associations between selected characteristics and inorganic dietary arsenic consumption among National Birth Defects Prevention Study control mothers, 1997–2011

	Inorganic arsenic (μg/day)							
	Low (<3.2) (*N* = 3,629)		Medium (3.2–5.5) (*N* = 3,629)		High (≥5.5) (*N* = 3,628)		Medium versus low	High versus low
Maternal characteristic	***N***	**(%)**	***N***	**(%)**	***N***	**(%)**	**OR (95% CI)**	**OR (95% CI)**
Age (years)[a]								
<20	481	13.3	254	7.0	300	8.3	0.5 (0.4, 0.6)	0.6 (0.5, 0.7)
20–24	930	25.6	714	19.7	772	21.3	0.7 (0.6, 0.8)	0.8 (0.7, 0.9)
25–29	995	27.4	1,065	29.4	993	27.4	Referent	Referent
30–34	815	22.5	1,050	28.9	970	26.7	1.2 (1.1, 1.4)	1.2 (1.0, 1.4)
35–39	332	9.2	470	13.0	489	13.5	1.3 (1.1, 1.6)	1.5 (1.3, 1.7)
≥40	76	2.1	76	2.1	104	2.9	0.9 (0.7, 1.3)	1.4 (1.0, 1.9)
Education (years)[a]								
0–8	155	4.3	179	5.0	204	5.7	1.5 (1.2, 2.0)	1.7 (1.4, 2.2)
9–11	467	13.0	330	9.2	432	12.0	0.9 (0.8, 1.1)	1.2 (1.0, 1.4)
12	1,007	28	754	20.9	771	21.4	Referent	Referent
13–15	1,034	28.8	994	27.6	883	24.5	1.3 (1.1, 1.5)	1.1 (1.0, 1.3)
≥16	934	26.0	1,346	37.4	1,317	36.5	1.9 (1.7, 2.2)	1.8 (1.6, 2.1)
Race/ethnicity								
Non-Hispanic White	2,304	63.5	2,333	64.3	1,777	49.0	Referent	Referent
Non-Hispanic Black	461	12.7	339	9.3	354	9.8	0.7 (0.6, 0.8)	1.0 (0.9, 1.2)
Hispanic	701	19.3	794	21.9	1,118	30.8	1.1 (1.0, 1.3)	2.1 (1.8, 2.3)
Other	161	4.4	163	4.5	377	10.4	1.0 (0.8, 1.3)	3.0 (2.5, 3.7)
Pre-pregnancy BMI (kg/m^2)								
<18.5	193	5.5	155	4.5	208	6.0	0.8 (0.6, 1.0)	1.0 (0.8, 1.3)
18.5–24.9	1,823	51.9	1,859	53.4	1,913	55.5	Referent	Referent
25–30.0	796	22.7	841	24.2	753	21.8	1.0 (0.9, 1.2)	0.9 (0.8, 1.0)
≥30.0	701	20	628	18	576	16.7	0.9 (0.8, 1.0)	0.8 (0.7, 0.9)
NBDPS site								
Arkansas	677	18.7	444	12.2	275	7.6	0.8 (0.7, 1.0)	0.6 (0.5, 0.8)
California	363	10.0	375	10.3	456	12.6	1.3 (1.1, 1.6)	1.9 (1.6, 2.3)
Georgia	310	8.5	376	10.4	375	10.3	1.5 (1.2, 1.8)	1.8 (1.5, 2.3)
Iowa	496	13.7	401	11.1	325	9.0	Referent	Referent
Massachusetts	274	7.6	450	12.4	556	15.3	2.0 (1.7, 2.5)	3.1 (2.5, 3.8)
New Jersey	110	3.0	175	4.8	269	7.4	2.0 (1.5, 2.6)	3.7 (2.9, 4.9)
New York	274	7.6	322	8.9	344	9.5	1.5 (1.2, 1.8)	1.9 (1.6, 2.4)
North Carolina	361	10.0	307	8.5	273	7.5	1.1 (0.9, 1.3)	1.2 (0.9, 1.4)
Texas	406	11.2	396	10.9	436	12.0	1.2 (1.0, 1.5)	1.6 (1.3, 2.0)
Utah	358	9.9	383	10.6	319	8.8	1.3 (1.1, 1.6)	1.4 (1.1, 1.7)
Alcohol use[b,c]								
No drinking	2,255	63.0	2,194	61.2	2,330	64.8	Referent	Referent
Drinking with no binge episodes	477	13.3	476	13.3	394	11.0	1.0 (0.9, 1.2)	0.8 (0.7, 0.9)
Drinking and ≥1 binge episode	849	23.7	915	25.5	874	24.3	1.1 (1.0, 1.2)	1.0 (0.9, 1.1)

(Continues)

TABLE 2 (Continued)

	Inorganic arsenic (μg/day)							
	Low (<3.2) (*N* = 3,629)		Medium (3.2–5.5) (*N* = 3,629)		High (≥5.5) (*N* = 3,628)		Medium versus low	High versus low
Maternal characteristic	***N***	**(%)**	***N***	**(%)**	***N***	**(%)**	**OR (95% CI)**	**OR (95% CI)**
Cigarette smoke exposure[b]								
No active or passive smoking	2,277	63.3	2,603	72.1	2,643	73.5	Referent	Referent
Active smoking only	328	9.1	264	7.3	227	6.3	0.7 (0.6, 0.8)	0.6 (0.5, 0.7)
Passive smoking only	509	14.2	398	11.0	433	12.0	0.7 (0.6, 0.8)	0.7 (0.6, 0.8)
Active and passive smoking	483	13.4	346	9.6	295	8.2	0.6 (0.5, 0.7)	0.5 (0.5, 0.6)

Abbreviations: BMI, body mass index; CI, confidence interval; NBDPS, National Birth Defects Prevention Study; OR, odds ratio.

[a]At delivery.

[b]During the period one month before conception through the third month of pregnancy.

[c]Binge episode defined as 4 or more drinks in one sitting.

more likely to be older (≥30 years), have lower (0–8 years) or higher (>12 years) education, be of non-Hispanic Black, Hispanic, or other race/ethnicity, and drink alcohol with no binge events during early pregnancy (odds ratios = 1.3–3.8); these mothers were less likely to be younger (<25 years), obese (≥30 kg/m^2), or exposed to cigarette smoke (active smoking only, active and passive smoking) early in pregnancy (odds ratios = 0.4–0.8) (Table 1). Additionally, mostly positive associations were observed for NBDPS site, using Iowa as the reference. Associations observed for inorganic dietary arsenic consumption were similar in direction as those for total arsenic, except for reduced associations for non-Hispanic Black mothers in the middle and high tertiles and reduced associations for mothers who reported early pregnancy alcohol use (Table 2). Results examining tertiles in μg/kg-bw/day were generally similar in direction to those examining tertiles in μg/day (data not shown).

4 | DISCUSSION

Among NBDPS control mothers, we estimated mean pre-pregnancy daily consumption of total and inorganic arsenic at 14.9 μg/day (0.23 μg/kg-bw/day) and 5.2 μg/day (0.08 μg/kg-bw/day), respectively. Our estimates for total and inorganic arsenic were higher than (total) or similar to (inorganic) those reported for U.S. reproductive-aged women reported during a contemporaneous time period (Jara & Winter, 2014). Compared to earlier reported estimates (1981–1996), our estimates were lower for total arsenic (reviewed in Agency for Toxic Substances and Disease Registry, 2007; Gunderson, 1988) but similar for inorganic arsenic (reviewed in Agency for Toxic Substances and Disease Registry, 2007). We identified several positive and inverse associations for selected maternal characteristics when comparing middle and high levels of total and inorganic arsenic consumption to the respective low levels. These novel data can help guide strategies to reduce pre-pregnancy dietary intake of arsenic among U.S. reproductive-aged women.

The previous studies and our current study used total arsenic concentration estimates provided by the TDS. Total arsenic is a composite measure of several arsenic species. Examination of total arsenic may mask the effects of harmful arsenic species, as arsenic metabolism and its associated toxicity varies depending on the species. Inorganic arsenic is metabolized into forms that are considered to be highly toxic (Thomas, Styblo, & Lin, 2001), whereas organic arsenic is excreted virtually unchanged in humans (Taylor et al., 2017). Although some foods (e.g., seafoods) are high in total arsenic, it is primarily organic, which is less harmful than inorganic arsenic (reviewed in Agency for Toxic Substances and Disease Registry, 2007).

Available information on inorganic arsenic in food is sparse, limiting dietary inorganic arsenic consumption estimation. A single study reported inorganic arsenic concentration estimates in food (Schoof et al., 1999); however, foods only were collected from two communities in Texas in 1997. These estimated inorganic arsenic concentrations may not accurately reflect concentrations in foods consumed throughout the U.S. due to the use of global food sources in the U.S. (Pirog, Van Pelt, Enshayan, & Cook, 2001) and the variability in concentrations in water used for cooking, which can influence the inorganic arsenic content in foods (Bae et al., 2002). These limitations underscore the need for improved estimates of inorganic arsenic content in foods.

Our study was strengthened by examining associations between maternal characteristics and pre-pregnancy dietary arsenic consumption among a nationally representative sample of U.S. women who delivered a liveborn child, which were not examined in previous studies, as well the use of individual FFQ reports and inorganic arsenic estimates for individual food items. Conversely, our study may have been limited by reliance on retrospective recall of pre-pregnancy diet; however, dietary recall among pregnant and nonpregnant women is similar (Ramage et al., 2015). Another limitation was that FFQ items for common sources of dietary arsenic, such as shrimp (organic) and rice (inorganic) (reviewed in Agency for Toxic Substances and Disease Registry, 2007), were omitted (shrimp) or grouped with other food items (rice). Also, total or inorganic arsenic estimates were not available for all FFQ items, underestimating dietary arsenic consumption. Additionally, wine may contain inorganic arsenic (Wilson, 2015), but its consumption was not queried separately. Finally, with the present data, it is difficult to meaningfully explore differences observed in arsenic consumption across NBDPS sites.

In summary, we estimated pre-pregnancy dietary arsenic consumption among a more contemporary, nationally representative sample of U.S. women who delivered a liveborn child. Associations between dietary arsenic consumption and several maternal characteristics also were observed. Currently, no consensus guidelines exist for dietary arsenic intake, and the Joint Food and Agriculture Organization/World Health Organization Expert Committee on Food Additives recently withdrew their provisional tolerable arsenic intake of 2.1 μg/kg-bw/day, as it was considered not protective of human health (Joint FAO/WHO Expert Committee on Food Additives, 2011). Similarly, the U.S. Environmental Protection Agency reference dose (daily dose likely to be without an appreciable risk of noncancer effects) for inorganic arsenic is 0.3 μg/kg-bw/day (reviewed in Agency for Toxic Substances and Disease Registry, 2007); however, this estimate was based on dermal and cardiovascular effects. As such, it is difficult to meaningfully interpret how reported levels of pre-pregnancy dietary arsenic consumption impact pregnancy outcomes. Additional research is needed to improve estimates of inorganic arsenic content in foods and better characterize arsenic consumption among this population, as well as its contribution to the development of birth defects.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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