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PRESENCE OF PFAAS IN DRINKING WATER ASSOCIATED WITH ELEVATED SERUM PFAAS IN CALIFORNIA WOMEN

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Introduction

Perfluoroalkyl acids (PFAAs) are a subset of the poly- and perfluoroalkyl substances (PFAS), a class of compounds widely used for over 60 years to impart non-stick, waterproof and stain-resistant coatings to a variety of consumer products.¹⁻⁴ PFAS are also found in aqueous film forming foams used to extinguish fuel fires.⁵ The objective of this study was to explore whether residence in an area where PFAAs have been detected in public drinking water corresponds to higher serum PFAA levels by linking biomonitoring data to the US EPA's Unregulated Contaminant Monitoring Rule (UCMR3) data.

Materials and Methods

Participants. We used serum PFAS measurements from 1,566 California women participating in a breast cancer case-control study nested within the California Teachers Study (CTS), a cohort study of over 133,000 female school employees.⁶ The characteristics of our participants reflect those of the CTS study from which it was drawn. As shown in Table 1, participants were mostly non-Hispanic white (77%); nearly 70% between the ages of 60-79 years; and 60% serving as controls in the breast cancer study from which they were drawn.

Blood samples. Non-fasting blood samples were collected during 2011-2013 in Tiger Top tubes, centrifuged, frozen and sent to the lab.

Serum PFAS. Serum samples were analyzed using an online SPE-HPLC- MS/MS method as described previously.⁷ Briefly, 100 μ L of serum were diluted in formic acid and spiked with isotopically labeled internal standards before injection into the online SPE-HPLC-MS/MS system (Symbiosis TM Pharma, IChrom Solutions, and ABSciex 4000 QTrap). Native and isotopically-labeled PFAS standards were purchased from Wellington Laboratories. Within each batch, two in-house spiked calf serum samples and NIST SRM 1958 were run in duplicate for quality control.

PFAA Detection in Drinking Water. We linked participants' residence to information on PFAAs occurrence in the UCMR3 data which includes drinking water samples from U.S. public water systems (PWSs) collected in 2013-2015.⁸ We created a proxy indicator for the occurrence of each PFAA in the drinking water of participants as follows: "detected" indicating that the particular PFAA was detected in at least one PWS serving their residential zip code; "not detected" indicating that the particular PFAA was not detected in any of the PWSs serving their residential zip code; and 'not tested' indicating that their residential zip code was not included in UCMR3.

Statistical Analysis. PFAA levels below the LOD were imputed as $LOD/\sqrt{2}$. Descriptive statistics for serum PFAAs are presented separately for those with and without detectable PFAAs in drinking water (Table 1). We used Wilcoxon Rank-Sum tests to evaluate whether serum levels differed between those with and without detectable levels of the given PFAA in their drinking water.

Results and Discussion

PFOS and PFOA were the most frequently detected PFAAs in the drinking water of 5.9% and 4.5% of participants, respectively. PFHpA and PFHxS were detected in the water of about 2% of participants. The levels of PFOA (mean=0.028 $\mu\text{g/L}$; range=0.020-0.053 $\mu\text{g/L}$) and PFOS (mean=0.058 $\mu\text{g/L}$; range=0.041 – 0.156 $\mu\text{g/L}$) that were detected in the water linked to our participants were all below the current U.S. EPA Provisional Health Advisory Levels of 0.4 $\mu\text{g/L}$ and 0.2 $\mu\text{g/L}$, respectively. The distribution of serum levels of PFOS and PFOA differed significantly between participants with and without detectable PFOA ($P < 0.0001$) and PFOS ($P = 0.0007$) in water (Table 2). Compared to those with no PFOA detected in their water, the median serum level among those with PFOA detected was 38% higher (3.46 ng/mL vs. 2.51 ng/mL). For PFOS, median serum levels were 29% higher among those for whom it was detected in the water compared to those in whom it was not (9.11 ng/mL vs. 7.08 ng/mL). In contrast, no statistically significant differences in the distributions of serum levels for PFHpA ($P = 0.36$) or PFHxS ($P = 0.60$) between participants with and without detectable levels in their water were observed. Results were similar when we repeated these analyses after removing the 622 breast cancer cases, with no differences noted for PFHpA or PFHxS but with significantly higher serum levels of PFOA ($P = 0.0004$) and PFOS ($P = 0.016$). These results suggest that drinking water with PFOS and PFOA at levels below current US EPA health advisory levels may contribute to higher serum levels. Given the health implications of these results, validation of our approach and replication of our findings in other populations should be a priority.

References

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Table 1. Demographics and Detection of PFAAs in Drinking Water for Study Participants

	Detection of PFAAs in Water*							
	All Participants		Detected		Not Detected		Not Tested	
	n	%	n	%	n	%	n	%
All	1,566	100	109	100	1,224	100	233	100
Age (years)								
40-49	90	6	7	6	71	6	12	5
50-59	240	15	16	15	192	16	32	14
60-69	606	39	46	42	470	38	90	39
70-79	476	30	30	28	376	31	70	30
≥80	154	10	10	9	115	9	29	12
Race/Ethnicity								
Non-Hispanic White	1,212	77	90	82	929	76	193	83
Black	100	6	1	1	87	7	12	5
Hispanic	116	8	5	5	99	8	12	5
Asian/Pacific Islander	112	7	11	10	86	7	15	6
Other	26	2	2	2	23	2	1	1
Cancer Status								
Control	944	60	64	59	746	61	134	58
Breast Cancer Case	622	40	45	41	478	39	99	43

*** Notes:**

* Detected = PFOS, PFOA, PFHxS or PFHpA detected in a PWS serving the zip code of residence;
Not Detected = None of PFOS, PFOA, PFHxS or PFHpA were detected in a PWS serving the zip code of residence;
Not Tested = PWS serving zip code was not tested (as reported by UCMR3).

Table 2. Serum PFAA Levels (ng/mL) in Participants with and without Detectable PFAAs in their Drinking Water.

PFAA in Drinking Water	PFAA Serum Level (ng/mL) [#]								
	n ^{**}	% [†]	Mean	GM	Median	Percentile		Max	P [§]
						P ₂₅	P ₇₅		
<i>PFHpA</i>									
D*	35	2.2	0.12	0.07	0.07	0.03	0.14	0.95	0.36
ND	1,298	82.9	0.09	0.06	0.05	0.03	0.11	1.61	
<i>PFHxS</i>									
D	31	2.0	1.87	1.35	1.48	0.91	2.91	5.07	0.60
ND	1,302	83.1	2.29	1.66	1.60	1.04	2.57	21.80	
<i>PFOA</i>									
D	70	4.5	4.06	3.47	3.46	2.54	4.83	17.00	<0.0001
ND	1,263	80.7	2.99	2.45	2.51	1.69	3.64	39.10	
<i>PFOS</i>									
D	93	5.9	11.02	8.51	9.11	5.02	13.70	39.40	0.0007
ND	1,240	79.2	8.42	6.76	7.08	4.45	10.60	99.80	

Notes:

* D = Detected; ND = Not Detected

** n = number of study participants (excludes 233 participants whose residential zip code was not included in the UCMR3 database).

† Percentages are expressed as percent of total number of study participants (n=1,566) and therefore do not sum to 100%.

[#]GM = geometric mean; P₂₅ = 25th-percentile; P₇₅ = 75th-percentile; Max = maximum.

[§] P = p-value from Wilcoxon Rank Sum Test.