

Supplemental Table 1. Sample-weighted geometric mean concentrations of lipophilic micronutrient biomarkers and persistent organic pollutants in serum. National Health and Nutrition Examination Survey, 2003-2004, aged 12 years and older.

Analyte	TCDD (fg/g)	PCB-74 (ng/g)	PCB-105 (ng/g)	PCB-153 (ng/g)	PBDE-47 (pg/g)	PFOA (ng/mL)	PFOS (ng/mL)	DDE (ng/g)
Males								
Pollutant	7.8 (0.4)	0.02 (0.001)	0.01 (0.0003)	0.1 (0.01)	122.2 (10.4)	4.4 (0.2)	23.6 (0.8)	1.4 (0.1)
<i>Vitamin A (µg/dL)</i>								
Retinyl palmitate	0.8 (0.04)	0.8 (0.04)	0.8 (0.04)	0.8 (0.04)	0.8 (0.05)	0.7 (0.04)	0.7 (0.04)	0.8 (0.1)
Retinyl stearate	0.2 (0.01)	0.2 (0.01)	0.2 (0.01)	0.2 (0.01)	0.2 (0.01)	0.2 (0.01)	0.2 (0.01)	0.2 (0.02)
Retinol	60.8 (1.0)	60.7 (0.9)	60.6 (0.9)	60.7 (0.9)	60.7 (1.0)	60.5 (0.9)	60.5 (0.9)	60.8 (1.0)
<i>Vitamin D (nmol/L)</i>								
25-Hydroxyvitamin D	62.8 (1.3)	62.4 (1.3)	62.0 (1.3)	62.4 (1.3)	60.5 (1.4)	60.3 (1.3)	60.3 (1.3)	60.4 (1.4)
<i>Vitamin E (µg/dL)</i>								
α-Tocopherol	1,167.4 (33.3)	1,164.4 (32.7)	1,162.1 (32.9)	1,164.4 (32.7)	1,139.5 (30.1)	1,117.6 (25.9)	1,117.6 (25.9)	1,143.8 (31.0)
δ-Tocopherol	4.8 (0.3)	4.8 (0.3)	4.9 (0.3)	4.8 (0.3)	5.5 (0.3)	5.2 (0.2)	5.2 (0.2)	5.6 (0.3)
γ-Tocopherol	183.3 (9.2)	183.2 (9.0)	183.6 (9.1)	183.2 (9.0)	199.3 (7.5)	194.5 (6.8)	194.5 (6.8)	202.6 (7.7)
<i>Carotenes (µg/dL)</i>								
α-Carotene	2.1 (0.1)	2.1 (0.1)	2.1 (0.1)	2.1 (0.1)	2.0 (0.1)	2.0 (0.1)	2.0 (0.1)	2.0 (0.1)
trans-β-Carotene	10.0 (0.5)	9.9 (0.5)	9.9 (0.5)	9.9 (0.5)	9.0 (0.5)	9.1 (0.4)	9.1 (0.4)	9.0 (0.5)
cis-β-Carotene	0.8 (0.04)	0.8 (0.04)	0.8 (0.04)	0.8 (0.04)	0.7 (0.04)	0.7 (0.03)	0.7 (0.03)	0.7 (0.04)
Total β-carotene	10.8 (0.5)	10.7 (0.5)	10.7 (0.5)	10.7 (0.5)	9.8 (0.5)	9.8 (0.4)	9.8 (0.4)	9.8 (0.5)
trans-Lycopene	20.3 (0.7)	20.3 (0.7)	20.3 (0.7)	20.3 (0.7)	18.7 (0.7)	20.5 (0.7)	20.5 (0.7)	18.7 (0.7)
cis-Lycopene	18.3 (0.7)	18.3 (0.7)	18.3 (0.7)	18.3 (0.7)	16.8 (0.6)	18.5 (0.6)	18.5 (0.6)	16.9 (0.6)
Total lycopene	39.0 (1.3)	38.9 (1.3)	38.9 (1.3)	38.9 (1.3)	35.7 (1.3)	39.2 (1.2)	39.2 (1.2)	35.8 (1.3)
Phytofluene	4.4 (0.2)	4.4 (0.2)	4.4 (0.2)	4.4 (0.2)	4.0 (0.2)	4.3 (0.1)	4.3 (0.1)	4.1 (0.2)
Phytoene	3.2 (0.2)	3.2 (0.2)	3.2 (0.2)	3.2 (0.2)	2.7 (0.1)	3.1 (0.1)	3.1 (0.1)	2.7 (0.1)
<i>Xanthophylls (µg/dL)</i>								
Lutein	8.9 (0.3)	8.9 (0.3)	8.9 (0.3)	8.9 (0.3)	8.3 (0.2)	9.0 (0.2)	9.0 (0.2)	8.3 (0.2)
Zeaxanthin	3.6 (0.1)	3.6 (0.1)	3.6 (0.1)	3.6 (0.1)	3.3 (0.1)	3.6 (0.1)	3.6 (0.1)	3.3 (0.1)
cis-Lutein/zeaxanthin	1.2 (0.04)	1.2 (0.04)	1.2 (0.04)	1.2 (0.04)	1.1 (0.03)	1.2 (0.03)	1.2 (0.03)	1.1 (0.03)
Combined lutein/zeaxanthin	13.9 (0.4)	13.9 (0.4)	14.0 (0.4)	13.9 (0.4)	12.9 (0.3)	13.9 (0.4)	13.9 (0.4)	12.9 (0.3)
α-Cryptoxanthin	2.2 (0.1)	2.2 (0.1)	2.2 (0.1)	2.2 (0.1)	2.1 (0.1)	2.2 (0.1)	2.2 (0.1)	2.1 (0.1)
β-Cryptoxanthin	6.9 (0.3)	6.8 (0.3)	6.7 (0.3)	6.8 (0.3)	6.4 (0.2)	6.3 (0.2)	6.3 (0.2)	6.4 (0.3)
Females								
Pollutant	8.5 (0.5)	0.03 (0.002)	0.01 (0.0005)	0.1 (0.01)	114.2 (8.5)	3.3 (0.1)	17.2 (0.6)	1.5 (0.1)
<i>Vitamin A (µg/dL)</i>								
Retinyl palmitate	0.7 (0.03)	0.7 (0.03)	0.7 (0.03)	0.7 (0.03)	0.7 (0.04)	0.6 (0.04)	0.6 (0.04)	0.7 (0.04)
Retinyl stearate	0.2 (0.01)	0.2 (0.01)	0.2 (0.01)	0.2 (0.01)	0.2 (0.01)	0.2 (0.01)	0.2 (0.01)	0.2 (0.01)
Retinol	53.2 (1.0)	52.8 (1.0)	52.9 (1.0)	52.8 (1.0)	52.4 (1.0)	54.7 (1.0)	54.7 (1.0)	52.4 (1.0)
<i>Vitamin D (nmol/L)</i>								
25-Hydroxyvitamin D	58.2 (1.8)	58.4 (1.8)	58.4 (1.8)	58.4 (1.8)	55.6 (1.5)	57.1 (1.6)	57.1 (1.6)	55.9 (1.5)
<i>Vitamin E (µg/dL)</i>								
α-Tocopherol	1,263.8 (35.4)	1,259.1 (35.2)	1,258.9 (35.4)	1,259.1 (35.2)	1,243.1 (34.8)	1,194.0 (41.8)	1,194.0 (41.8)	1,247.1 (35.4)
δ-Tocopherol	4.6 (0.2)	4.5 (0.2)	4.5 (0.2)	4.5 (0.2)	4.6 (0.2)	5.0 (0.3)	5.0 (0.3)	4.6 (0.2)
γ-Tocopherol	189.4 (8.6)	187.1 (8.4)	186.1 (8.4)	187.1 (8.4)	185.7 (7.7)	195.6 (8.7)	195.6 (8.7)	186.4 (7.9)
<i>Carotenes (µg/dL)</i>								
α-Carotene	2.7 (0.2)	2.6 (0.2)	2.7 (0.2)	2.6 (0.2)	2.6 (0.2)	2.6 (0.2)	2.6 (0.2)	2.6 (0.2)
trans-β-Carotene	12.7 (0.7)	12.7 (0.7)	12.7 (0.7)	12.7 (0.7)	12.5 (0.7)	11.9 (0.7)	11.9 (0.7)	12.8 (0.7)
cis-β-Carotene	1.0 (0.05)	1.0 (0.05)	1.0 (0.05)	1.0 (0.05)	1.0 (0.05)	1.0 (0.1)	1.0 (0.1)	1.0 (0.1)
Total β-Carotene	13.7 (0.7)	13.7 (0.7)	13.7 (0.8)	13.7 (0.7)	13.6 (0.7)	12.9 (0.7)	12.9 (0.7)	13.8 (0.7)

trans-Lycopene	19.3 (0.7)	19.2 (0.7)	19.1 (0.7)	19.2 (0.7)	18.8 (0.7)	19.4 (0.7)	19.4 (0.7)	19.1 (0.7)
cis-Lycopene	16.7 (0.6)	16.7 (0.6)	16.6 (0.6)	16.7 (0.6)	16.7 (0.6)	16.8 (0.6)	16.8 (0.6)	16.9 (0.6)
Total lycopene	36.1 (1.2)	36.0 (1.2)	35.8 (1.2)	36.0 (1.2)	35.8 (1.2)	36.3 (1.2)	36.3 (1.2)	36.2 (1.2)
Phytofluene	3.8 (0.2)	3.8 (0.2)	3.8 (0.2)	3.8 (0.2)	4.2 (0.2)	4.4 (0.2)	4.4 (0.2)	4.3 (0.2)
Phytoene	2.7 (0.1)	2.7 (0.1)	2.7 (0.1)	2.7 (0.1)	2.9 (0.1)	3.1 (0.2)	3.1 (0.2)	2.9 (0.1)
<i>Xanthophylls (µg/dL)</i>								
Lutein	8.7 (0.3)	8.7 (0.3)	8.7 (0.3)	8.7 (0.3)	8.8 (0.3)	8.8 (0.3)	8.8 (0.3)	8.8 (0.3)
Zeaxanthin	3.3 (0.1)	3.3 (0.1)	3.3 (0.1)	3.3 (0.1)	3.2 (0.1)	3.3 (0.1)	3.3 (0.1)	3.3 (0.1)
cis-Lutein/Zeaxanthin	1.2 (0.04)	1.2 (0.04)	1.2 (0.04)	1.2 (0.04)	1.2 (0.04)	1.3 (0.04)	1.3 (0.04)	1.2 (0.04)
Combined lutein/zeaxanthin	13.5 (0.5)	13.4 (0.4)	13.4 (0.5)	13.4 (0.4)	13.4 (0.4)	13.5 (0.4)	13.5 (0.4)	13.5 (0.4)
α-Cryptoxanthin	2.1 (0.1)	2.1 (0.1)	2.1 (0.1)	2.1 (0.1)	2.1 (0.1)	2.2 (0.1)	2.2 (0.1)	2.2 (0.1)
β-Cryptoxanthin	6.8 (0.3)	6.8 (0.3)	6.8 (0.3)	6.8 (0.3)	6.6 (0.3)	6.5 (0.3)	6.5 (0.3)	6.7 (0.3)

Supplemental Table 1. All concentrations presented as geometric mean (GM) with corresponding standard error (SE). Abbreviations for persistent organic pollutants (POPs) are as follows: 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), polychlorinated biphenyl 74 (PCB-74), polychlorinated biphenyl 105 (PCB-105), polychlorinated biphenyl 153 (PCB-153), polybrominated diphenyl ether 47 (PBDE-47), perfluorooctanoic acid (PFOA), perfluorooctanesulfonic acid (PFOS), p,p'-dichlorodiphenyldichloroethylene (DDE).

Supplemental Table 2. Adjusted associations between lipophilic micronutrient levels and persistent organic pollutant concentrations in males: modified by age and body mass index. National Health and Nutrition Examination Survey, 2003-2004, aged 12 years and older.

Micronutrient biomarker	TCDD (N=381)	PCB-74 (N=396)	PCB-105 (N=393)	PCB-153 (N=396)	PBDE-47 (N=434)	PFOA (N=468)	PFOS (N=468)	DDE (N=420)
	β , p-value	β , p-value	β , p-value	β , p-value	β , p-value	β , p-value	β , p-value	β , p-value
Age (y)								
<i>Vitamin A</i>								
Retinyl palmitate	0.002, 0.373	-0.001, 0.706	0.000, 0.921	-0.001, 0.803	0.005, 0.220	-0.005, 0.066	-0.003, 0.092	0.001, 0.696
Retinyl stearate	0.002, 0.205	0.001, 0.663	0.002, 0.423	0.002, 0.388	0.004, 0.276	-0.004, 0.105	-0.002, 0.254	0.005, 0.130
Retinol	0.011, 0.105	0.005, 0.519	-0.007, 0.480	0.002, 0.861	-0.020, 0.210	-0.018, 0.072	-0.011, 0.191	-0.016, 0.185
<i>Vitamin D</i>								
25-Hydroxyvitamin D	-0.013, 0.066	-0.012, 0.083	-0.015, 0.029*	-0.016, 0.027*	-0.017, 0.122	-0.004, 0.461	0.001, 0.687	-0.019, 0.040*
<i>Vitamin E</i>								
α -Tocopherol	0.002, 0.698	0.002, 0.701	0.002, 0.467	-0.010, 0.072	0.026, 0.009*	-0.012, 0.034*	-0.003, 0.363	0.005, 0.602
δ -Tocopherol	0.004, 0.136	0.007, 0.052	0.004, 0.308	0.013, 0.003*	0.004, 0.524	-0.003, 0.494	-0.003, 0.389	0.005, 0.262
γ -Tocopherol	0.007, 0.006*	0.005, 0.215	0.005, 0.195	0.010, 0.035*	0.005, 0.470	-0.008, 0.059	-0.005, 0.077	0.004, 0.263
<i>Carotenes</i>								
α -Carotene	0.000, 0.808	0.001, 0.703	0.001, 0.858	-0.005, 0.172	0.000, 0.984	-0.001, 0.684	0.002, 0.161	-0.001, 0.784
trans- β -Carotene	-0.001, 0.792	-0.003, 0.324	-0.004, 0.375	-0.010, 0.043*	-0.001, 0.923	-0.002, 0.544	0.001, 0.609	0.001, 0.804
cis- β -Carotene	-0.001, 0.571	-0.003, 0.277	-0.005, 0.222	-0.010, 0.020*	-0.001, 0.927	-0.004, 0.342	0.000, 0.853	0.001, 0.901
total β -Carotene	-0.001, 0.793	-0.003, 0.334	-0.004, 0.371	-0.010, 0.041*	0.000, 0.934	-0.002, 0.548	0.001, 0.615	0.001, 0.814
trans-Lycopene	0.003, 0.394	0.000, 0.859	-0.003, 0.351	0.009, 0.0004*	-0.002, 0.818	-0.004, 0.173	0.000, 0.845	-0.001, 0.811
cis-Lycopene	0.002, 0.309	0.001, 0.682	0.000, 0.978	0.005, 0.016*	-0.004, 0.611	-0.006, 0.064	0.000, 0.820	0.000, 0.976
total Lycopene	0.003, 0.295	0.000, 0.898	-0.002, 0.498	0.009, 0.001*	-0.002, 0.741	-0.005, 0.090	0.000, 0.985	-0.001, 0.925
Phytofluene	0.003, 0.279	0.004, 0.044*	0.005, 0.118	0.007, 0.002*	-0.006, 0.210	-0.005, 0.042*	-0.002, 0.229	-0.001, 0.839
Phytoene	0.001, 0.758	0.000, 0.788	0.000, 0.988	0.002, 0.244	-0.004, 0.419	-0.003, 0.285	0.000, 0.718	-0.003, 0.427
<i>Xanthophylls</i>								
Lutein	-0.001, 0.825	0.001, 0.836	0.002, 0.724	-0.007, 0.057	-0.001, 0.867	-0.003, 0.354	0.001, 0.656	-0.001, 0.891
Zeaxanthin	0.002, 0.627	0.001, 0.827	0.002, 0.629	-0.003, 0.556	-0.001, 0.943	-0.004, 0.291	0.003, 0.379	0.005, 0.472
cis-Lutein/zeaxanthin	-0.001, 0.742	0.001, 0.799	0.003, 0.450	-0.004, 0.225	-0.011, 0.183	-0.007, 0.038*	-0.003, 0.358	0.002, 0.838
Combined Lutein/zeaxanthin	0.000, 0.963	0.001, 0.811	0.002, 0.646	-0.008, 0.061	-0.001, 0.870	-0.004, 0.283	0.002, 0.637	0.002, 0.780
α -Cryptoxanthin	0.004, 0.223	-0.002, 0.440	0.001, 0.742	0.001, 0.705	-0.007, 0.457	-0.001, 0.801	0.003, 0.318	0.002, 0.779
β -Cryptoxanthin	0.003, 0.338	0.000, 0.860	0.003, 0.285	-0.003, 0.299	-0.007, 0.367	0.000, 0.884	0.002, 0.364	0.000, 0.944
Normal weight								
<i>Vitamin A</i>								
Retinyl palmitate	-0.269, 0.003*	-0.169, 0.120	-0.069, 0.647	-0.150, 0.339	-0.131, 0.492	0.134, 0.175	0.080, 0.159	0.095, 0.506
Retinyl stearate	-0.208, 0.007*	-0.215, 0.080	-0.083, 0.507	-0.060, 0.630	-0.231, 0.195	0.072, 0.486	-0.030, 0.688	-0.147, 0.335
Retinol	-0.387, 0.070	-0.536, 0.091	0.093, 0.823	-0.568, 0.184	0.050, 0.948	0.142, 0.750	0.167, 0.685	-0.072, 0.880
<i>Vitamin D</i>								
25-Hydroxyvitamin D	0.264, 0.291	0.146, 0.547	0.009, 0.979	0.082, 0.793	0.197, 0.703	0.109, 0.470	-0.014, 0.937	0.334, 0.432
<i>Vitamin E</i>								
α -Tocopherol	-0.478, 0.049*	-0.428, 0.100	-0.619, 0.058	-0.025, 0.940	-1.806, 0.003*	0.544, 0.181	0.276, 0.220	0.029, 0.961
δ -Tocopherol	-0.119, 0.327	-0.269, 0.041*	-0.222, 0.197	-0.526, 0.002*	-0.101, 0.663	0.424, 0.007*	0.261, 0.015*	-0.142, 0.471
γ -Tocopherol	-0.064, 0.421	-0.127, 0.360	-0.042, 0.693	-0.185, 0.381	-0.121, 0.787	0.681, 0.031*	0.391, 0.010*	-0.120, 0.702
<i>Carotenes</i>								
α -Carotene	0.001, 0.990	-0.030, 0.720	0.052, 0.706	0.302, 0.067	0.009, 0.964	-0.130, 0.119	-0.121, 0.127	0.154, 0.131
trans- β -Carotene	0.010, 0.913	0.091, 0.337	0.173, 0.317	0.445, 0.038*	-0.160, 0.511	-0.157, 0.262	-0.113, 0.287	-0.017, 0.931
cis- β -Carotene	0.034, 0.708	0.098, 0.318	0.227, 0.135	0.497, 0.019*	-0.072, 0.797	-0.088, 0.591	-0.031, 0.793	0.047, 0.825
total β -Carotene	0.009, 0.921	0.089, 0.356	0.173, 0.322	0.449, 0.037*	-0.163, 0.509	-0.156, 0.275	-0.110, 0.309	-0.012, 0.952
trans-Lycopene	-0.119, 0.339	-0.069, 0.607	0.024, 0.906	-0.420, 0.013*	-0.042, 0.919	0.340, 0.068	0.163, 0.215	-0.095, 0.744

cis-Lycopene	-0.135, 0.191	-0.037, 0.766	0.015, 0.931	-0.239, 0.059	0.164, 0.672	0.413, 0.026*	0.174, 0.299	-0.107, 0.745
total Lycopene	-0.137, 0.244	-0.059, 0.644	0.017, 0.928	-0.351, 0.019*	0.047, 0.909	0.395, 0.035*	0.178, 0.239	-0.110, 0.729
Phytofluene	-0.037, 0.668	-0.121, 0.149	-0.153, 0.244	-0.209, 0.026*	0.356, 0.190	0.226, 0.171	0.156, 0.207	0.121, 0.547
Phytoene	-0.013, 0.897	-0.032, 0.692	0.075, 0.524	-0.028, 0.841	0.277, 0.269	0.071, 0.535	-0.038, 0.647	0.329, 0.078
<i>Xanthophylls</i>								
Lutein	0.059, 0.670	0.081, 0.562	0.094, 0.664	0.632, 0.012*	0.095, 0.805	0.137, 0.580	-0.009, 0.965	0.369, 0.191
Zeaxanthin	-0.105, 0.571	0.010, 0.963	0.003, 0.989	0.387, 0.155	-0.071, 0.881	0.233, 0.190	0.093, 0.582	-0.021, 0.927
cis-Lutein/Zeaxanthin	-0.011, 0.905	0.039, 0.747	0.054, 0.803	0.420, 0.048*	0.646, 0.138	0.261, 0.184	0.235, 0.259	0.295, 0.331
Combined Lutein/zeaxanthin	0.014, 0.914	0.060, 0.669	0.089, 0.706	0.719, 0.014*	0.065, 0.885	0.177, 0.478	0.027, 0.899	0.227, 0.441
α-Cryptoxanthin	-0.004, 0.972	0.187, 0.013*	0.188, 0.194	0.237, 0.144	0.514, 0.217	-0.353, 0.107	-0.211, 0.218	0.374, 0.381
β-Cryptoxanthin	-0.071, 0.535	0.010, 0.874	-0.056, 0.657	0.164, 0.137	0.460, 0.207	-0.166, 0.374	-0.082, 0.389	0.303, 0.313
Overweight								
<i>Vitamin A</i>								
Retinyl palmitate	0.130, 0.207	0.219, 0.192	0.082, 0.698	0.133, 0.587	0.056, 0.826	0.096, 0.416	-0.014, 0.879	-0.194, 0.152
Retinyl stearate	0.011, 0.893	0.143, 0.409	-0.034, 0.873	-0.111, 0.603	-0.046, 0.810	0.068, 0.575	0.023, 0.793	-0.203, 0.038*
Retinol	-0.663, 0.013*	0.148, 0.615	0.055, 0.906	0.474, 0.247	-0.740, 0.294	0.549, 0.424	0.226, 0.580	0.169, 0.739
<i>Vitamin D</i>								
25-Hydroxyvitamin D	0.240, 0.376	0.233, 0.296	0.738, 0.020*	0.649, 0.030*	0.671, 0.208	-0.222, 0.444	-0.293, 0.226	0.679, 0.051
<i>Vitamin E</i>								
α-Tocopherol	0.475, 0.033*	0.288, 0.163	0.169, 0.587	0.436, 0.132	0.020, 0.961	0.142, 0.676	-0.155, 0.494	-0.043, 0.887
δ-Tocopherol	-0.131, 0.359	-0.237, 0.023*	-0.043, 0.741	-0.184, 0.165	-0.071, 0.807	-0.202, 0.292	-0.040, 0.615	-0.012, 0.952
γ-Tocopherol	-0.352, 0.004*	-0.225, 0.031*	-0.256, 0.138	-0.373, 0.031*	-0.424, 0.250	-0.275, 0.227	-0.038, 0.715	-0.087, 0.695
<i>Carotenes</i>								
α-Carotene	0.010, 0.898	-0.005, 0.946	-0.121, 0.250	-0.091, 0.426	-0.047, 0.832	0.225, 0.052	-0.027, 0.731	-0.039, 0.808
trans-β-Carotene	0.010, 0.936	-0.030, 0.782	-0.155, 0.375	-0.083, 0.637	0.242, 0.428	0.280, 0.067	0.027, 0.763	0.075, 0.596
cis-β-Carotene	-0.039, 0.798	0.015, 0.910	-0.098, 0.567	-0.117, 0.543	0.282, 0.398	0.316, 0.073	0.015, 0.857	0.059, 0.686
total β-Carotene	0.008, 0.953	-0.025, 0.819	-0.148, 0.398	-0.082, 0.641	0.248, 0.417	0.281, 0.068	0.024, 0.789	0.073, 0.609
trans-Lycopene	0.084, 0.587	0.041, 0.773	0.083, 0.649	0.048, 0.743	0.075, 0.845	-0.243, 0.048*	-0.182, 0.329	-0.176, 0.568
cis-Lycopene	0.186, 0.086	-0.006, 0.941	-0.003, 0.979	0.074, 0.513	-0.134, 0.695	-0.197, 0.074	-0.247, 0.190	-0.248, 0.464
total Lycopene	0.100, 0.486	0.014, 0.914	0.072, 0.675	0.004, 0.975	-0.023, 0.951	-0.231, 0.047*	-0.219, 0.256	-0.212, 0.521
Phytofluene	0.069, 0.448	-0.002, 0.987	0.040, 0.769	-0.074, 0.489	0.029, 0.921	-0.123, 0.430	-0.166, 0.216	-0.155, 0.535
Phytoene	0.077, 0.479	0.043, 0.519	0.078, 0.631	0.000, 0.998	-0.099, 0.662	-0.002, 0.991	-0.133, 0.271	-0.133, 0.626
<i>Xanthophylls</i>								
Lutein	0.129, 0.406	-0.133, 0.184	-0.255, 0.045*	-0.133, 0.311	-0.277, 0.341	-0.178, 0.450	-0.274, 0.051	-0.320, 0.204
Zeaxanthin	0.080, 0.715	-0.149, 0.508	-0.293, 0.361	-0.343, 0.218	-0.152, 0.726	-0.213, 0.235	-0.331, 0.030*	-0.241, 0.593
cis-Lutein/Zeaxanthin	0.114, 0.498	-0.176, 0.058	-0.311, 0.106	-0.296, 0.077	0.345, 0.328	-0.132, 0.467	-0.314, 0.031*	-0.050, 0.889
Combined Lutein/zeaxanthin	0.138, 0.437	-0.157, 0.219	-0.324, 0.071	-0.281, 0.147	-0.270, 0.391	-0.208, 0.379	-0.333, 0.039*	-0.332, 0.300
α-Cryptoxanthin	-0.135, 0.478	-0.086, 0.704	-0.487, 0.132	-0.340, 0.280	-0.091, 0.830	0.372, 0.102	0.021, 0.883	-0.437, 0.346
β-Cryptoxanthin	0.104, 0.439	-0.040, 0.806	-0.317, 0.124	-0.078, 0.719	0.048, 0.904	0.118, 0.438	-0.113, 0.337	-0.111, 0.753
Obese								
<i>Vitamin A</i>								
Retinyl palmitate	0.048, 0.739	0.264, 0.108	0.058, 0.756	0.192, 0.377	-0.007, 0.963	0.139, 0.235	0.090, 0.282	-0.106, 0.348
Retinyl stearate	-0.062, 0.604	0.142, 0.392	-0.097, 0.583	0.030, 0.861	0.148, 0.447	0.157, 0.166	0.136, 0.100	0.010, 0.934
Retinol	0.251, 0.439	0.492, 0.305	0.266, 0.628	0.959, 0.146	1.022, 0.286	1.199, 0.094	0.611, 0.234	0.807, 0.082
<i>Vitamin D</i>								
25-Hydroxyvitamin D	0.062, 0.802	0.060, 0.809	0.280, 0.367	0.463, 0.147	0.092, 0.853	0.175, 0.484	-0.057, 0.722	0.163, 0.630
<i>Vitamin E</i>								
α-Tocopherol	0.490, 0.012*	0.544, 0.006*	0.510, 0.079	0.698, 0.032*	0.036, 0.944	0.146, 0.693	-0.053, 0.793	0.347, 0.366
δ-Tocopherol	-0.161, 0.183	-0.042, 0.697	0.019, 0.871	-0.069, 0.638	0.210, 0.452	-0.181, 0.285	-0.094, 0.368	-0.153, 0.542
γ-Tocopherol	-0.359, 0.010*	-0.162, 0.190	-0.272, 0.172	-0.386, 0.106	-0.208, 0.678	-0.003, 0.985	-0.028, 0.866	0.013, 0.961
<i>Carotenes</i>								

α -Carotene	0.001, 0.990	-0.016, 0.868	-0.099, 0.329	-0.067, 0.605	-0.006, 0.984	0.058, 0.735	-0.109, 0.418	0.005, 0.959
trans- β -Carotene	-0.075, 0.469	-0.046, 0.595	-0.195, 0.150	0.007, 0.963	-0.034, 0.910	0.115, 0.511	-0.079, 0.517	0.066, 0.611
cis- β -Carotene	-0.117, 0.318	-0.016, 0.873	-0.146, 0.263	0.042, 0.814	-0.075, 0.843	0.188, 0.394	-0.127, 0.262	0.203, 0.239
total β -Carotene	-0.079, 0.451	-0.045, 0.612	-0.190, 0.158	0.011, 0.943	-0.039, 0.898	0.117, 0.512	-0.086, 0.485	0.073, 0.574
trans-Lycopene	-0.207, 0.369	-0.186, 0.226	-0.184, 0.347	-0.337, 0.065	0.097, 0.817	-0.014, 0.918	-0.127, 0.406	0.186, 0.613
cis-Lycopene	-0.122, 0.548	-0.224, 0.047*	-0.271, 0.085	-0.294, 0.062	0.055, 0.893	-0.013, 0.939	-0.235, 0.175	0.212, 0.589
total Lycopene	-0.203, 0.388	-0.212, 0.124	-0.201, 0.321	-0.380, 0.043*	0.074, 0.861	-0.014, 0.928	-0.185, 0.266	0.204, 0.599
Phytofluene	-0.178, 0.205	-0.146, 0.060	-0.165, 0.264	-0.323, 0.006*	0.016, 0.957	0.015, 0.933	-0.114, 0.358	0.102, 0.766
Phytoene	-0.096, 0.530	-0.017, 0.789	-0.131, 0.299	-0.196, 0.054	0.054, 0.811	0.133, 0.503	-0.050, 0.701	0.048, 0.868
<i>Xanthophylls</i>								
Lutein	-0.204, 0.356	0.006, 0.975	0.017, 0.903	-0.190, 0.465	-0.421, 0.393	0.086, 0.750	-0.100, 0.539	0.000, 1.000
Zeaxanthin	-0.047, 0.805	-0.041, 0.802	-0.007, 0.961	-0.246, 0.300	-0.689, 0.046*	0.223, 0.238	-0.149, 0.291	-0.696, 0.142
cis-Lutein/Zeaxanthin	-0.142, 0.531	0.016, 0.929	0.060, 0.658	-0.215, 0.409	-0.582, 0.094	0.066, 0.767	-0.265, 0.144	-0.012, 0.978
Combined Lutein/zeaxanthin	-0.168, 0.449	-0.005, 0.979	-0.002, 0.987	-0.294, 0.316	-0.678, 0.128	0.136, 0.619	-0.132, 0.432	-0.220, 0.662
α -Cryptoxanthin	-0.145, 0.275	0.034, 0.805	-0.080, 0.596	-0.188, 0.362	-0.813, 0.054	0.507, 0.010*	0.022, 0.881	-0.568, 0.215
β -Cryptoxanthin	-0.024, 0.870	-0.012, 0.920	-0.100, 0.451	-0.118, 0.441	-0.356, 0.327	0.116, 0.388	-0.076, 0.584	-0.285, 0.345

Supplemental Table 2. In 381 – 468 male participants, associations (regression estimate coefficient, p-value) for each pair of natural log-transformed serum micronutrient biomarker and persistent organic pollutant (POP) by effect measure modifier using a multiple linear regression model. An asterisk (*) denotes value is statistically significant at the 5% significance level. Abbreviations for persistent organic pollutants (POPs) are as follows: 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), polychlorinated biphenyl 74 (PCB-74), polychlorinated biphenyl 105 (PCB-105), polychlorinated biphenyl 153 (PCB-153), polybrominated diphenyl ether 47 (PBDE-47), perfluorooctanoic acid (PFOA), perfluorooctanesulfonic acid (PFOS), p,p'-dichlorodiphenyldichloroethylene (DDE). Body mass index (BMI) was categorized for participants aged 12 – 19 years old with BMI-for-age percentiles by sex using the 2000 Centers for Disease Control and Prevention (CDC) growth charts and for participants 20 years old and older by weight in kilograms divided by height (meters²). Participants considered underweight were excluded due to small sample size. All models adjusted for race and ethnicity, serum cotinine, and poverty-to-income ratio (PIR). PFOA and PFOS modeled without adjusting for total serum lipids. Only models with vitamin D biomarker as a predictor adjusted for 6-month exam period.

Supplemental Table 3. Adjusted associations between lipophilic micronutrient levels and persistent organic pollutant concentrations in females: modified by age and body mass index. National Health and Nutrition Examination Survey, 2003-2004, aged 12 years and older.

Micronutrient biomarker	TCDD (N=381)	PCB-74 (N=396)	PCB-105 (N=393)	PCB-153 (N=396)	PBDE-47 (N=434)	PFOA (N=468)	PFOS (N=468)	DDE (N=420)
	β , p-value	β , p-value	β , p-value	β , p-value	β , p-value	β , p-value	β , p-value	β , p-value
Age (y)								
<i>Vitamin A</i>								
Retinyl palmitate	0.004, 0.147	0.000, 0.920	0.001, 0.686	-0.005, 0.073	0.002, 0.616	-0.001, 0.562	-0.002, 0.387	-0.001, 0.769
Retinyl stearate	0.003, 0.242	0.001, 0.831	0.001, 0.831	-0.005, 0.050	-0.002, 0.682	-0.002, 0.385	-0.003, 0.303	-0.001, 0.826
Retinol	0.010, 0.026*	-0.006, 0.272	-0.013, 0.126	-0.012, 0.092	0.008, 0.601	-0.012, 0.144	-0.018, 0.046*	-0.015, 0.214
<i>Vitamin D</i>								
25-Hydroxyvitamin D	0.002, 0.611	-0.004, 0.363	-0.011, 0.113	-0.010, 0.087	0.001, 0.946	-0.009, 0.068	-0.010, 0.028*	-0.011, 0.054
<i>Vitamin E</i>								
α -Tocopherol	0.011, 0.006*	0.002, 0.660	0.002, 0.591	-0.013, 0.003*	0.002, 0.819	0.003, 0.333	0.000, 0.948	-0.019, 0.011*
δ -Tocopherol	0.003, 0.111	0.003, 0.302	0.005, 0.197	0.004, 0.052	0.009, 0.114	-0.002, 0.540	0.002, 0.537	0.008, 0.073
γ -Tocopherol	0.002, 0.477	0.002, 0.421	0.004, 0.445	0.005, 0.227	0.007, 0.307	0.000, 0.883	0.004, 0.368	0.014, <.0001*
<i>Carotenes</i>								
α -Carotene	0.000, 0.856	-0.001, 0.775	0.003, 0.348	-0.004, 0.213	0.003, 0.183	0.000, 0.803	0.000, 0.957	-0.002, 0.606
trans- β -Carotene	0.001, 0.498	0.000, 0.979	0.003, 0.353	-0.004, 0.319	0.006, 0.126	-0.001, 0.685	0.001, 0.616	-0.005, 0.087
cis- β -Carotene	0.001, 0.739	0.000, 0.865	0.003, 0.337	-0.004, 0.232	0.007, 0.100	0.000, 0.868	0.000, 0.800	-0.004, 0.100
total β -Carotene	0.001, 0.492	0.000, 0.954	0.003, 0.343	-0.004, 0.320	0.006, 0.124	-0.001, 0.696	0.001, 0.636	-0.005, 0.084
trans-Lycopene	0.003, 0.340	0.007, 0.033*	0.005, 0.303	0.010, 0.024*	0.006, 0.197	-0.004, 0.133	-0.001, 0.779	0.004, 0.281
cis-Lycopene	0.003, 0.430	0.007, 0.088	0.002, 0.668	0.007, 0.146	0.001, 0.846	-0.001, 0.647	0.000, 0.974	0.005, 0.232
total Lycopene	0.003, 0.366	0.007, 0.047*	0.004, 0.431	0.009, 0.055	0.004, 0.534	-0.003, 0.273	0.000, 0.895	0.005, 0.249
Phytofluene	-0.003, 0.327	-0.002, 0.540	-0.006, 0.139	-0.004, 0.187	0.000, 0.933	-0.003, 0.146	-0.003, 0.219	0.005, 0.168
Phytoene	-0.001, 0.417	0.002, 0.502	0.005, 0.023*	0.001, 0.659	0.002, 0.736	-0.002, 0.382	0.000, 0.842	0.003, 0.342
<i>Xanthophylls</i>								
Lutein	0.003, 0.410	0.001, 0.668	0.007, 0.150	-0.005, 0.149	-0.013, 0.058	0.002, 0.635	0.003, 0.319	-0.011, 0.133
Zeaxanthin	0.007, 0.032*	0.003, 0.449	0.012, 0.039*	-0.002, 0.587	-0.014, 0.074	0.000, 0.934	0.001, 0.837	-0.009, 0.069
cis-Lutein/zeaxanthin	-0.001, 0.761	0.002, 0.573	0.008, 0.125	-0.005, 0.172	-0.018, 0.006*	0.003, 0.443	0.004, 0.126	-0.010, 0.166
Combined Lutein/zeaxanthin	0.004, 0.283	0.003, 0.482	0.010, 0.089	-0.006, 0.136	-0.017, 0.024*	0.002, 0.618	0.004, 0.347	-0.013, 0.126
α -Cryptoxanthin	-0.002, 0.497	0.002, 0.562	0.006, 0.150	0.001, 0.824	-0.009, 0.134	0.001, 0.899	0.005, 0.285	0.001, 0.880
β -Cryptoxanthin	-0.001, 0.512	0.000, 0.965	0.005, 0.082	-0.004, 0.122	-0.003, 0.527	-0.002, 0.452	0.002, 0.558	-0.003, 0.419
Normal weight								
<i>Vitamin A</i>								
Retinyl palmitate	-0.221, 0.058	-0.160, 0.200	-0.297, 0.199	-0.034, 0.745	-0.344, 0.098	0.103, 0.404	0.032, 0.789	-0.084, 0.651
Retinyl stearate	-0.174, 0.021*	-0.151, 0.142	-0.160, 0.315	0.037, 0.672	-0.082, 0.738	0.158, 0.189	0.087, 0.514	-0.250, 0.227
Retinol	-0.347, 0.121	0.123, 0.561	0.420, 0.085	0.529, 0.156	-0.208, 0.823	0.688, 0.029*	0.740, 0.049*	0.488, 0.431
<i>Vitamin D</i>								
25-Hydroxyvitamin D	-0.047, 0.782	0.093, 0.615	0.501, 0.020*	0.502, 0.054	0.395, 0.269	0.516, 0.014*	0.399, 0.006*	0.440, 0.066
<i>Vitamin E</i>								
α -Tocopherol	-0.745, 0.006*	-0.275, 0.217	-0.650, 0.038*	0.359, 0.195	-0.400, 0.482	-0.073, 0.655	0.007, 0.946	0.664, 0.228
δ -Tocopherol	-0.091, 0.345	-0.046, 0.782	-0.225, 0.375	-0.226, 0.156	-0.177, 0.591	0.200, 0.103	0.083, 0.484	-0.140, 0.480
γ -Tocopherol	0.054, 0.718	0.014, 0.936	-0.058, 0.823	-0.124, 0.567	0.151, 0.735	0.071, 0.592	-0.020, 0.913	-0.397, 0.073
<i>Carotenes</i>								
α -Carotene	-0.134, 0.071	-0.046, 0.683	-0.098, 0.495	0.285, 0.056	-0.278, 0.133	-0.096, 0.229	-0.168, 0.021*	0.009, 0.947
trans- β -Carotene	-0.193, 0.113	-0.127, 0.163	-0.179, 0.195	0.195, 0.220	-0.463, 0.110	-0.047, 0.606	-0.205, 0.020*	0.314, 0.104
cis- β -Carotene	-0.216, 0.147	-0.144, 0.195	-0.186, 0.265	0.269, 0.122	-0.499, 0.082	-0.053, 0.612	-0.190, 0.037*	0.254, 0.204
total β -Carotene	-0.195, 0.115	-0.128, 0.160	-0.181, 0.192	0.199, 0.211	-0.468, 0.108	-0.047, 0.612	-0.205, 0.021*	0.314, 0.106
trans-Lycopene	-0.245, 0.320	-0.500, 0.032*	-0.299, 0.379	-0.412, 0.103	0.013, 0.972	0.173, 0.371	0.055, 0.728	-0.133, 0.628

cis-Lycopene	-0.303, 0.204	-0.538, 0.042*	-0.209, 0.585	-0.339, 0.270	0.131, 0.736	0.041, 0.803	0.003, 0.983	-0.304, 0.354
total Lycopene	-0.287, 0.256	-0.544, 0.034*	-0.277, 0.454	-0.400, 0.160	0.068, 0.866	0.116, 0.523	0.032, 0.844	-0.238, 0.456
Phytofluene	0.066, 0.679	-0.052, 0.774	0.169, 0.465	0.139, 0.440	0.276, 0.320	0.059, 0.504	-0.044, 0.731	-0.183, 0.351
Phytoene	-0.072, 0.464	-0.077, 0.651	-0.220, 0.158	0.013, 0.934	0.302, 0.166	-0.005, 0.962	-0.115, 0.223	0.087, 0.588
<i>Xanthophylls</i>								
Lutein	-0.364, 0.025*	-0.087, 0.697	-0.073, 0.767	0.570, 0.045*	0.655, 0.104	-0.206, 0.442	-0.246, 0.203	0.393, 0.379
Zeaxanthin	-0.338, 0.049*	-0.201, 0.456	-0.331, 0.200	0.444, 0.089	0.686, 0.057	-0.153, 0.589	-0.025, 0.925	0.353, 0.262
cis-Lutein/Zeaxanthin	-0.149, 0.438	-0.172, 0.467	-0.224, 0.450	0.529, 0.030*	0.861, 0.007*	-0.238, 0.227	-0.373, 0.024*	0.512, 0.216
Combined Lutein/zeaxanthin	-0.425, 0.014*	-0.191, 0.523	-0.189, 0.538	0.697, 0.031*	0.857, 0.045*	-0.242, 0.427	-0.266, 0.238	0.490, 0.320
α-Cryptoxanthin	-0.086, 0.500	-0.206, 0.115	-0.374, 0.010*	-0.066, 0.731	0.439, 0.222	-0.051, 0.802	-0.296, 0.165	0.071, 0.816
β-Cryptoxanthin	-0.038, 0.680	-0.074, 0.506	-0.231, 0.118	0.208, 0.179	0.032, 0.888	0.084, 0.487	-0.132, 0.317	0.318, 0.192
Overweight								
<i>Vitamin A</i>								
Retinyl palmitate	-0.053, 0.687	0.131, 0.132	0.031, 0.822	0.237, 0.042*	0.005, 0.978	-0.042, 0.642	0.068, 0.456	-0.026, 0.867
Retinyl stearate	-0.029, 0.798	0.090, 0.294	0.033, 0.774	0.230, 0.058	-0.023, 0.901	-0.074, 0.519	0.020, 0.825	0.005, 0.973
Retinol	-0.225, 0.376	0.228, 0.254	0.299, 0.387	0.126, 0.666	-0.888, 0.260	0.361, 0.218	0.329, 0.175	-0.266, 0.298
<i>Vitamin D</i>								
25-Hydroxyvitamin D	-0.060, 0.801	0.253, 0.112	0.163, 0.623	0.017, 0.925	-0.687, 0.113	-0.036, 0.804	0.028, 0.812	-0.493, 0.038*
<i>Vitamin E</i>								
α-Tocopherol	-0.028, 0.802	0.319, 0.027*	0.395, 0.079	0.363, 0.052	0.057, 0.877	-0.011, 0.905	0.147, 0.156	0.502, 0.078
δ-Tocopherol	-0.014, 0.936	0.020, 0.891	0.203, 0.215	0.029, 0.867	-0.065, 0.647	-0.112, 0.319	-0.132, 0.389	-0.140, 0.342
γ-Tocopherol	-0.025, 0.845	-0.183, 0.288	-0.046, 0.774	-0.236, 0.220	-0.686, 0.009*	-0.119, 0.423	-0.184, 0.122	-0.313, 0.138
<i>Carotenes</i>								
α-Carotene	-0.008, 0.924	0.001, 0.987	-0.186, 0.163	-0.155, 0.198	0.324, 0.093	0.131, 0.057	0.195, 0.018*	0.300, 0.056
trans-β-Carotene	0.027, 0.771	0.022, 0.771	-0.192, 0.171	-0.1390, 0.284,	0.225, 0.310	0.089, 0.134	0.219, 0.070	0.114, 0.496
cis-β-Carotene	0.056, 0.648	0.010, 0.895	-0.206, 0.129	-0.190, 0.189	0.235, 0.291	0.077, 0.269	0.249, 0.054	0.136, 0.454
total β-Carotene	0.027, 0.778	0.019, 0.798	-0.195, 0.163	-0.145, 0.267	0.225, 0.310	0.088, 0.141	0.222, 0.069	0.116, 0.490
trans-Lycopene	-0.136, 0.532	0.119, 0.471	-0.004, 0.985	-0.106, 0.368	-0.159, 0.547	-0.046, 0.759	-0.089, 0.435	0.256, 0.416
cis-Lycopene	-0.089, 0.659	0.228, 0.192	0.052, 0.806	-0.021, 0.850	-0.074, 0.786	-0.077, 0.675	-0.078, 0.610	0.414, 0.262
total Lycopene	-0.119, 0.578	0.178, 0.303	0.029, 0.893	-0.062, 0.575	-0.124, 0.648	-0.061, 0.715	-0.086, 0.520	0.336, 0.335
Phytofluene	-0.109, 0.495	0.009, 0.931	-0.217, 0.201	-0.066, 0.557	-0.245, 0.050	0.003, 0.986	0.162, 0.259	0.148, 0.592
Phytoene	-0.069, 0.602	0.016, 0.889	-0.109, 0.470	-0.046, 0.672	-0.362, 0.073	0.074, 0.417	0.138, 0.220	-0.049, 0.807
<i>Xanthophylls</i>								
Lutein	0.000, 0.999	0.067, 0.588	-0.394, 0.015*	-0.250, 0.181	-0.017, 0.940	0.029, 0.915	0.218, 0.332	0.600, 0.008*
Zeaxanthin	-0.086, 0.687	-0.005, 0.977	-0.394, 0.037*	-0.379, 0.128	-0.089, 0.792	-0.052, 0.853	-0.098, 0.700	0.291, 0.386
cis-Lutein/Zeaxanthin	-0.011, 0.947	0.073, 0.590	-0.291, 0.122	-0.205, 0.199	0.214, 0.341	0.081, 0.672	0.253, 0.125	0.427, 0.154
Combined Lutein/zeaxanthin	0.011, 0.955	0.069, 0.644	-0.425, 0.023*	-0.339, 0.096	-0.038, 0.888	0.016, 0.959	0.190, 0.437	0.556, 0.066
α-Cryptoxanthin	-0.062, 0.744	-0.075, 0.589	-0.323, 0.189	-0.165, 0.539	0.091, 0.776	0.102, 0.599	0.201, 0.354	0.179, 0.583
β-Cryptoxanthin	-0.109, 0.416	-0.056, 0.616	-0.250, 0.215	-0.168, 0.345	0.076, 0.689	-0.002, 0.984	0.027, 0.803	0.028, 0.904
Obese								
<i>Vitamin A</i>								
Retinyl palmitate	0.161, 0.190	0.242, 0.041*	0.241, 0.212	0.321, 0.022*	0.377, 0.011*	-0.092, 0.380	-0.032, 0.670	0.186, 0.295
Retinyl stearate	0.130, 0.284	0.204, 0.075	0.143, 0.425	0.309, 0.037*	0.267, 0.122	-0.185, 0.046*	-0.055, 0.567	0.315, 0.103
Retinol	0.116, 0.554	0.364, 0.232	0.500, 0.325	0.223, 0.549	0.100, 0.833	-0.248, 0.230	-0.176, 0.488	0.316, 0.259
<i>Vitamin D</i>								
25-Hydroxyvitamin D	0.223, 0.219	0.239, 0.105	0.280, 0.332	0.096, 0.368	-0.438, 0.242	-0.016, 0.921	-0.093, 0.545	-0.241, 0.240
<i>Vitamin E</i>								
α-Tocopherol	0.280, 0.218	0.330, 0.113	0.562, 0.078	0.590, 0.017*	0.707, 0.055	-0.370, 0.019*	-0.033, 0.808	0.721, 0.118
δ-Tocopherol	0.029, 0.842	-0.002, 0.990	0.031, 0.881	0.140, 0.414	-0.369, 0.215	-0.136, 0.405	-0.069, 0.505	-0.231, 0.291
γ-Tocopherol	-0.028, 0.858	-0.138, 0.388	-0.081, 0.659	-0.161, 0.348	-0.798, 0.021*	-0.106, 0.472	0.017, 0.842	-0.360, 0.176
<i>Carotenes</i>								

α -Carotene	0.145, 0.117	0.039, 0.639	-0.059, 0.675	-0.075, 0.441	0.347, 0.036*	-0.139, 0.176	0.061, 0.468	0.083, 0.610	
trans- β -Carotene	0.144, 0.132	0.041, 0.606	-0.065, 0.665	-0.002, 0.984	0.550, 0.029*	-0.103, 0.415	0.040, 0.689	0.028, 0.894	
cis- β -Carotene	0.272, 0.009*	0.105, 0.185	-0.064, 0.733	0.073, 0.614	0.557, 0.018*	-0.190, 0.244	0.031, 0.785	0.149, 0.429	
total β -Carotene	0.153, 0.107	0.044, 0.577	-0.069, 0.655	-0.001, 0.995	0.548, 0.030*	-0.110, 0.395	0.040, 0.696	0.034, 0.873	
trans-Lycopene	-0.068, 0.587	-0.173, 0.118	-0.114, 0.539	-0.212, 0.128	-0.269, 0.494	0.434, 0.002*	0.263, 0.038*	-0.115, 0.744	
cis-Lycopene	0.045, 0.745	-0.106, 0.419	-0.042, 0.859	-0.135, 0.405	-0.030, 0.945	0.340, 0.038*	0.246, 0.045*	0.089, 0.829	
total Lycopene	-0.015, 0.905	-0.145, 0.220	-0.081, 0.694	-0.181, 0.220	-0.160, 0.710	0.404, 0.007*	0.263, 0.039*	-0.002, 0.995	
Phytofluene	-0.001, 0.993	-0.054, 0.583	0.066, 0.655	-0.045, 0.653	-0.301, 0.358	0.110, 0.276	0.228, 0.057	-0.098, 0.774	
Phytoene	0.123, 0.172	-0.119, 0.267	-0.050, 0.810	-0.130, 0.309	-0.359, 0.172	0.023, 0.833	0.224, 0.023*	-0.204, 0.467	
<i>Xanthophylls</i>									
Lutein	0.177, 0.442	-0.040, 0.850	-0.162, 0.577	-0.181, 0.472	0.540, 0.165	0.033, 0.874	0.305, 0.076	0.520, 0.032*	
Zeaxanthin	-0.083, 0.693	-0.225, 0.363	-0.484, 0.068	-0.445, 0.088	0.751, 0.066	0.184, 0.435	0.331, 0.077	0.322, 0.234	
cis-Lutein/Zeaxanthin	0.121, 0.531	-0.095, 0.632	-0.212, 0.485	-0.278, 0.172	0.622, 0.100	-0.032, 0.871	0.312, 0.049*	0.431, 0.093	
Combined Lutein/zeaxanthin	0.162, 0.498	-0.073, 0.765	-0.252, 0.411	-0.314, 0.233	0.680, 0.113	0.071, 0.763	0.350, 0.072	0.511, 0.057	
α -Cryptoxanthin	0.156, 0.239	-0.086, 0.478	-0.188, 0.365	-0.111, 0.633	0.496, 0.232	0.047, 0.803	0.259, 0.116	0.133, 0.594	
β -Cryptoxanthin	0.061, 0.641	-0.135, 0.258	-0.201, 0.301	-0.108, 0.498	0.420, 0.105	-0.022, 0.887	0.156, 0.135	0.018, 0.928	

Supplemental Table 3. In 399 – 442 female participants, associations (regression estimate coefficient, p-value) for each pair of natural log-transformed serum micronutrient biomarker and persistent organic pollutant (POP) by effect measure modifier using a multiple linear regression model. An asterisk (*) denotes value is statistically significant at the 5% significance level. Abbreviations for persistent organic pollutants (POPs) are as follows: 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), polychlorinated biphenyl 74 (PCB-74), polychlorinated biphenyl 105 (PCB-105), polychlorinated biphenyl 153 (PCB-153), polybrominated diphenyl ether 47 (PBDE-47), perfluorooctanoic acid (PFOA), perfluorooctanesulfonic acid (PFOS), p,p'-dichlorodiphenyldichloroethylene (DDE). Body mass index (BMI) was categorized for participants aged 12 – 19 years old with BMI-for-age percentiles by sex using the 2000 Centers for Disease Control and Prevention (CDC) growth charts and for participants 20 years old and older by weight in kilograms divided by height (meters²). Participants considered underweight were excluded due to small sample size. All models adjusted for race and ethnicity, serum cotinine, and poverty-to-income ratio (PIR). PFOA and PFOS modeled without adjusting for total serum lipids. Only models with vitamin D biomarker as a predictor adjusted for 6-month exam period.