SUPPLEMENTARY INFORMATION

Fine particulate matter from burning oil and gas and neurological symptoms among oil spill cleanup workers during cleanup and 1-3 years later

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Figures/Tables

Table A1. Summary metrics for average and cumulative maximum daily exposure to burning/flaring-related $PM_{2.5}$ for oil spill cleanup and response workers not missing data on symptoms during the *DWH* disaster (n=9,044).

	N (%)	Concentration
Average maximum daily exposure		*(µg/m³)*
Referent	7066 (78.1)	<1
In situ burn workers (low)	41 (0.5)	10
Hot zone/source workers (low)	1628 (18.0)	29
Hot zone workers (high)	309 (3.4)	97
Cumulative maximum daily exposure		*Range [median] (µg/m³-days)*
Referent	7066 (78.1)	<1 [0]
Low	591 (6.5)	10 – 679 [86]
Medium	604 (6.7)	689 – 1378 [689]
High	783 (8.7)	1406 – 4071 [1406]

Table A2. Summary metrics for average and cumulative maximum daily exposure to burning/flaring-related $PM_{2.5}$ for oil spill cleanup and response workers not missing data on symptoms 1-3 years after the *DWH* disaster (n=9,274).

	N (%)	Concentration
Average maximum daily exposure		*(µg/m³)*
Referent	7240 (78.1)	<1
In situ burn workers (low)	42 (0.5)	10
Hot zone/source workers (low)	1679 (18.1)	29
Hot zone workers (high)	313 (3.4)	97
Cumulative maximum daily exposure		*Range [median] (µg/m³-days)*
Referent	7240 (78.1)	<1 [0]
Low	609 (6.6)	10 – 679 [86]
Medium	619 (6.7)	689 – 1378 [689]
High	806 (8.7)	1406 – 4071 [1406]

Table A3. Characteristics of the analytic study population (n=9,914) by $PM_{2.5}$ exposure group. Gender, smoking, alcohol, education, race, ethnicity, age, and body mass index data were collected at enrollment.

	Cumulative $PM_{2.5}$ exposure				Average $PM_{2.5}$ exposure		
	Referent (n=7849)	**Tertile 1 (n=622)**	**Tertile 2 (n=629)**	**Tertile 3 (n=814)**	**Referent (n=7849)**	**Low (n=1750)**	**High (n=315)**
		n (%)				n (%)	
Gender							
Female	761 (9.7)	66 (10.6)	63 (10.0)	46 (5.7)	761 (9.7)	160 (9.1)	15 (4.8)
Male	7088 (90.3)	556 (89.4)	566 (90.0)	768 (94.4)	7088 (90.3)	1590 (90.9)	300 (95.2)
Missing	0	0	0	0	0	0	0
Lifetime smoking							
Heavy current smoker	942 (13.0)	48 (8.0)	59 (9.5)	91 (11.4)	942 (13.0)	173 (10.1)	25 (8.0)
Light current smoker	1429 (19.7)	161 (26.7)	141 (22.7)	197 (24.6)	1429 (19.7)	428 (25.0)	71 (22.8)
Former smoker	1667 (22.9)	108 (17.9)	124 (20.0)	158 (19.7)	1667 (22.9)	321 (18.7)	69 (22.2)
Never smoker	3230 (44.4)	287 (47.5)	296 (47.7)	356 (44.4)	3230 (44.4)	793 (46.2)	146 (47.0)
Missing (n)	581	18	9	12	581	35	4
Lifetime consumption of alcohol							
Current drinker	5665 (77.4)	474 (77.6)	486 (77.5)	630 (77.7)	5665 (77.4)	1347 (77.6)	243 (77.4)
Former drinker	1284 (17.5)	94 (15.4)	94 (15.0)	131 (16.2)	1284 (17.5)	271 (15.6)	48 (15.3)
Never drinker	373 (5.1)	43 (7.0)	47 (7.5)	50 (6.2)	373 (5.1)	117 (6.7)	23 (7.3)
Missing (n)	527	11	2	3	527	15	1
Highest educational attainment							
Less than high school/equivalent	1398 (19.1)	120 (19.6)	103 (16.4)	142 (17.4)	1398 (19.1)	320 (18.4)	45 (14.3)
High school diploma/GED	2256 (30.7)	167 (27.3)	220 (35.1)	299 (36.7)	2256 (30.7)	558 (32.1)	128 (40.6)
Some college/2-year degree	2229 (30.4)	185 (30.3)	197 (31.4)	271 (33.3)	2229 (30.4)	559 (32.2)	94 (29.8)
4 Year college graduate or more	1456 (19.8)	139 (22.8)	107 (17.1)	102 (12.5)	1456 (19.8)	300 (17.3)	48 (15.2)
Missing (n)	510	11	2	0	510	13	0
Race							
White	5589 (71.6)	354 (57.2)	343 (54.8)	460 (56.9)	5589 (71.6)	977 (56.2)	180 (57.3)
Black	942 (12.1)	192 (31.0)	197 (31.5)	268 (33.1)	942 (12.1)	555 (31.9)	102 (32.5)

Other	1278 (16.4)	73 (11.8)	86 (13.7)	81 (10.0)	1278 (16.4)	208 (12.0)	32 (10.2)
Missing (n)	40	3	3	5	40	10	1
Ethnicity							
Hispanic	486 (6.2)	55 (8.9)	58 (9.2)	54 (6.7)	486 (6.2)	143 (8.2)	24 (7.6)
Non-Hispanic	7335 (93.8)	565 (91.1)	570 (90.8)	758 (93.4)	7335 (93.8)	1603 (91.8)	290 (92.4)
Missing (n)	28	2	1	2	28	4	1
		Mean (standard deviation)				Mean (standard deviation)	
Age (years)	42.5 (12.8)	38.2 (11.3)	39.0 (11.7)	38.6 (11.3)	42.5 (12.8)	38.4 (11.6)	40.0 (10.8)
Missing (n)	4	0	0	0	4	0	0
Body mass index (kg/m^2)	28.5 (6.2)	28.1 (5.5)	28.0 (5.7)	28.7 (5.3)	28.5 (6.2)	28.2 (5.5)	29.0 (5.7)
Missing (n)	564	17	6	3	564	24	2
BTEX-H exposure (ppb-days) *	7409.7 (5410.7)	8010.6 (8620.8)	11156.9 (9779.5)	17609.1 (13111.1)	7409.7 (5410.7)	12488.4 (11121.4)	14220.2 (14235.3)

*Sum of average daily exposures across all days of work; there are no individuals missing this exposure

Table A4. Number of individuals, by gender and overall, who reported experiencing symptoms during the *DWH* disaster and, separately, 1-3 years after the *DWH* disaster. Central nervous system (CNS) symptoms include dizziness, sweating, palpitations, nausea, and migraine; peripheral nervous system (PNS) symptoms include tingling or numbness in extremities, blurred vision, and stumbling.

	During *DWH* disaster			**1-3 years after *DWH* disaster**		
Outcome	*Female (n)*	*Male (n)*	*Total (n)*	*Female (n)*	*Male (n)*	*Total (n)*
Any neurological	335	2921	3256	345	2547	2892
2 or more neurological	198	1537	1735	184	1398	1582
Any CNS	244	1945	2189	235	1588	1823
2 or more CNS	115	871	986	96	680	776
Any PNS	113	1087	1200	175	1455	1630
2 or more PNS	38	308	346	57	406	463
Blurred vision	49	416	465	78	576	654
Dizziness	86	595	681	63	501	564
Fatigue	220	1676	1896	182	1235	1417
Migraine(s)	180	1145	1325	184	1069	1253
Nausea	60	440	500	39	352	391
Heart palpitations	38	302	340	31	248	279
Stumbling	20	241	261	32	241	273
Excessive sweating	86	1023	1109	76	617	693
Tingling or numbness in the extremities	91	812	903	140	1151	1291
Insomnia*	107	877	984	84	585	669
Seizure(s)*	13	109	122	10	99	109
Vomiting*	48	346	394	70	488	558

*Added to questionnaire after some interviews were already completed.

Table A5. Number of individuals, by race, who reported experiencing symptoms during the *DWH* disaster and, separately, 1-3 years after the *DWH* disaster. Central nervous system (CNS) symptoms include dizziness, sweating, palpitations, nausea, and migraine; peripheral nervous system (PNS) symptoms include tingling or numbness in extremities, blurred vision, and stumbling.

	During *DWH* disaster				**1-3 years after *DWH* disaster**			
Outcome	*White (n)*	*Black (n)*	*Other (n)*	*Missing (n)*	*White (n)*	*Black (n)*	*Other (n)*	*Missing (n)*
Any neurological	1949	909	382	16	1721	799	357	15
2 or more neurological	898	615	213	10	851	530	194	7
Any CNS	1161	750	267	11	953	630	232	8
2 or more CNS	428	432	119	7	350	331	94	1
Any PNS	656	379	158	7	968	441	211	10
2 or more PNS	140	163	42	1	236	160	63	4
Blurred vision	212	182	69	2	348	203	99	4
Dizziness	266	326	85	4	246	237	80	1
Fatigue	1172	518	197	9	840	409	162	6
Migraine(s)	689	464	163	9	637	454	155	7
Nausea	212	215	70	3	188	155	48	0
Heart palpitations	150	142	46	2	141	107	30	1
Stumbling	129	103	28	1	137	107	27	2
Excessive sweating	563	434	108	4	316	300	76	1
Tingling or numbness in the extremities	482	305	110	6	773	346	162	10
Insomnia*	657	182	139	6	430	121	115	3
Seizure(s)*	65	33	24	0	62	25	22	0
Vomiting*	179	163	51	1	289	196	72	1

* Added to questionnaire after some interviews were already completed.

Table A6. Distribution of symptoms experienced by time point. For each symptom, the group (i.e., only during the *DWH* disaster; only 1-3 years after the *DWH* disaster; at both times) with the highest frequency is **bolded** as this was identified as the most common trajectory for that symptom.

	Prevalence of symptom by time of experience (n [%])			**Prevalence of symptom persistence (%)** *	**Most common symptom trajectory identified**
Outcome	Only during *DWH* disaster (*Resolved*)	Only 1-3 years after *DWH* disaster (*New onset*)	At both times (*Persisted*)		
Blurred vision	163 (0.22)	**331 (0.44)**	260 (0.34)	0.61	*New onset*
Dizziness	**379 (0.42**)	264 (0.29)	252 (0.28)	0.40	*Resolved*
Fatigue	**954 (0.42)**	485 (0.22)	809 (0.36)	0.46	*Resolved*
Tingling or numbness in the extremities	273 (0.19)	**630 (0.43**)	565 (0.38)	0.67	*New onset*
Migraine	489 (0.3)	418 (0.25)	**741 (0.45**)	0.60	*Persisted*
Stumbling while walking	146 (0.37)	**154 (0.39**)	100 (0.25)	0.41	*New onset*
Heart palpitations	**203 (0.44)**	140 (0.3)	118 (0.26)	0.37	*Resolved*
Excessive sweating	**634 (0.5)**	217 (0.17)	418 (0.33)	0.40	*Resolved*
Nausea	**293 (0.44)**	195 (0.3)	171 (0.26)	0.37	*Resolved*
Insomnia	352 (0.38)	195 (0.21)	**387 (0.41)**	0.52	*Persisted*
Seizures	**67 (0.4)**	53 (0.32)	47 (0.28)	0.41	*Resolved*
Vomiting	165 (0.24)	**323 (0.47)**	198 (0.29)	0.55	*New onset*

*Among participants who reported the symptom at the time of the spill.

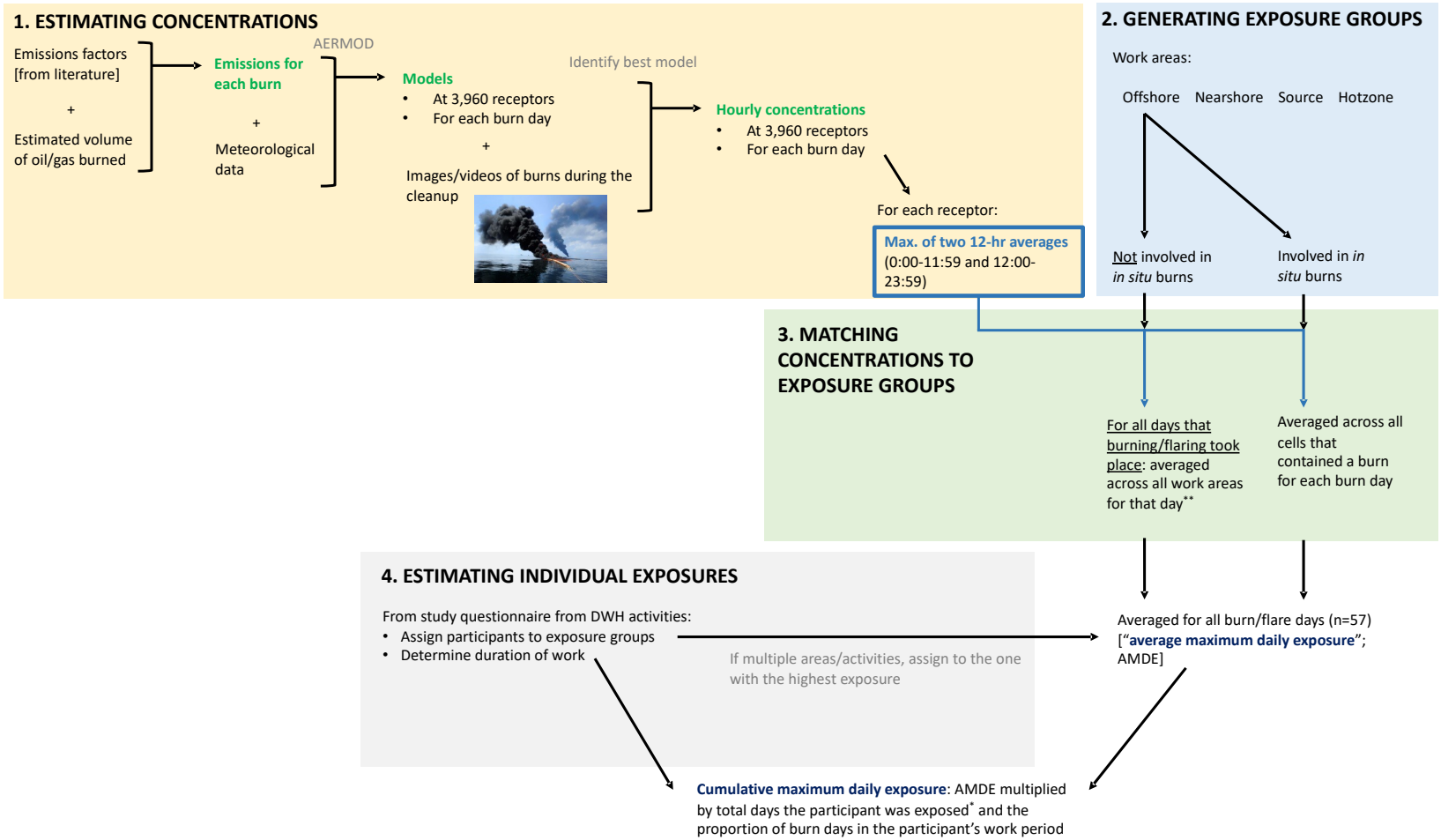

Figure A1. Schematic of how $PM_{2.5}$ exposures were estimated for individuals included in analysis. Black text indicates data inputs or details about the data, green text indicates an output generated from the previous step in the schematic and in blue are the exposure metrics included in the exposure assessment database. *The total days a person was exposed was estimated as end date of work minus start date of work; **This action was undertaken for the hot zone and hot zone/source as well. "Receptors" are locations in the Gulf.

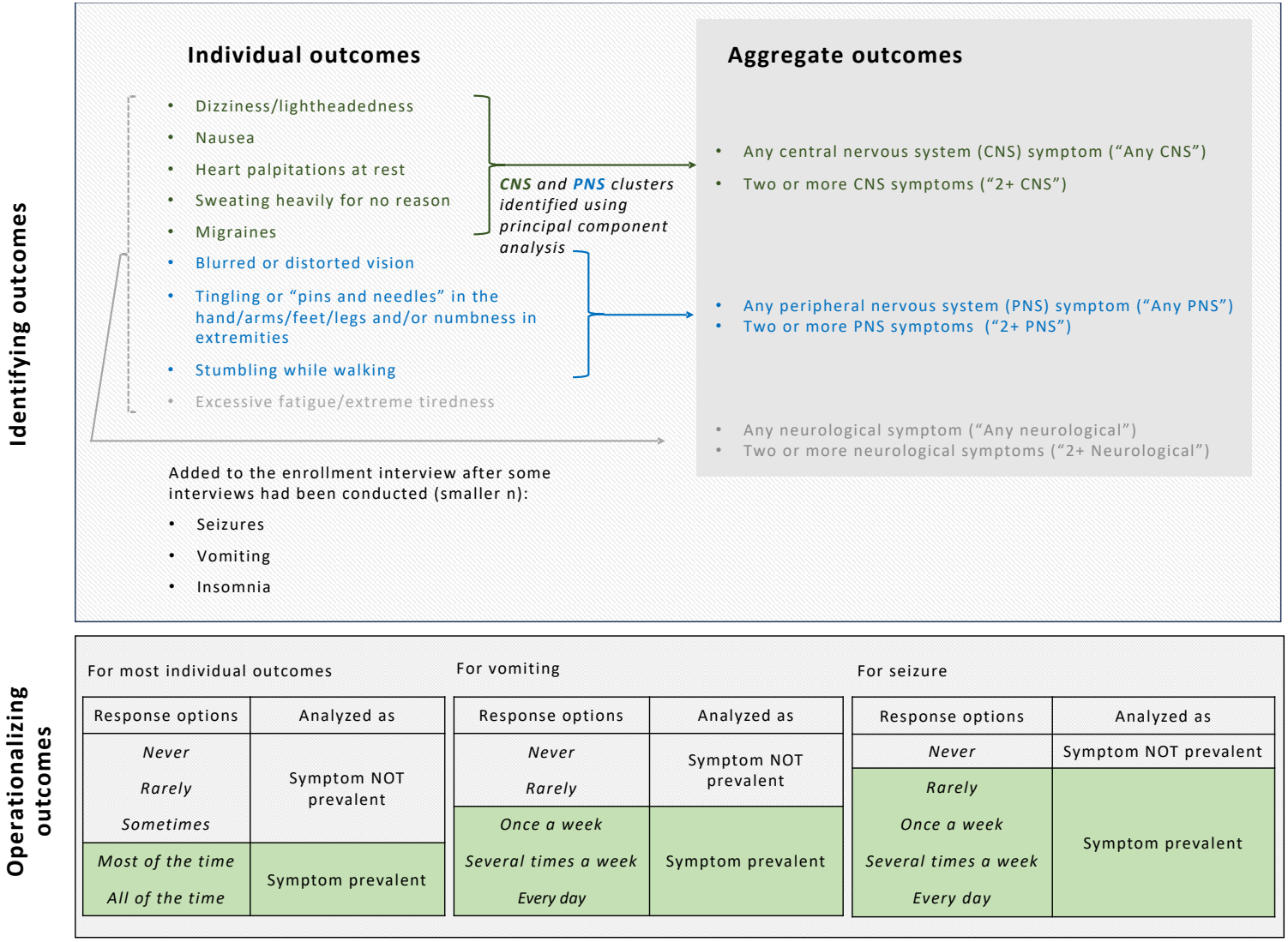

Figure A2. Overview of how the outcomes were defined and operationalized for analysis based on the responses of individuals to questions about their experience of 12 individual symptoms during the *DWH* disaster and 1-3 years after the *DWH* disaster. Questions about these symptoms were asked in the enrollment interview

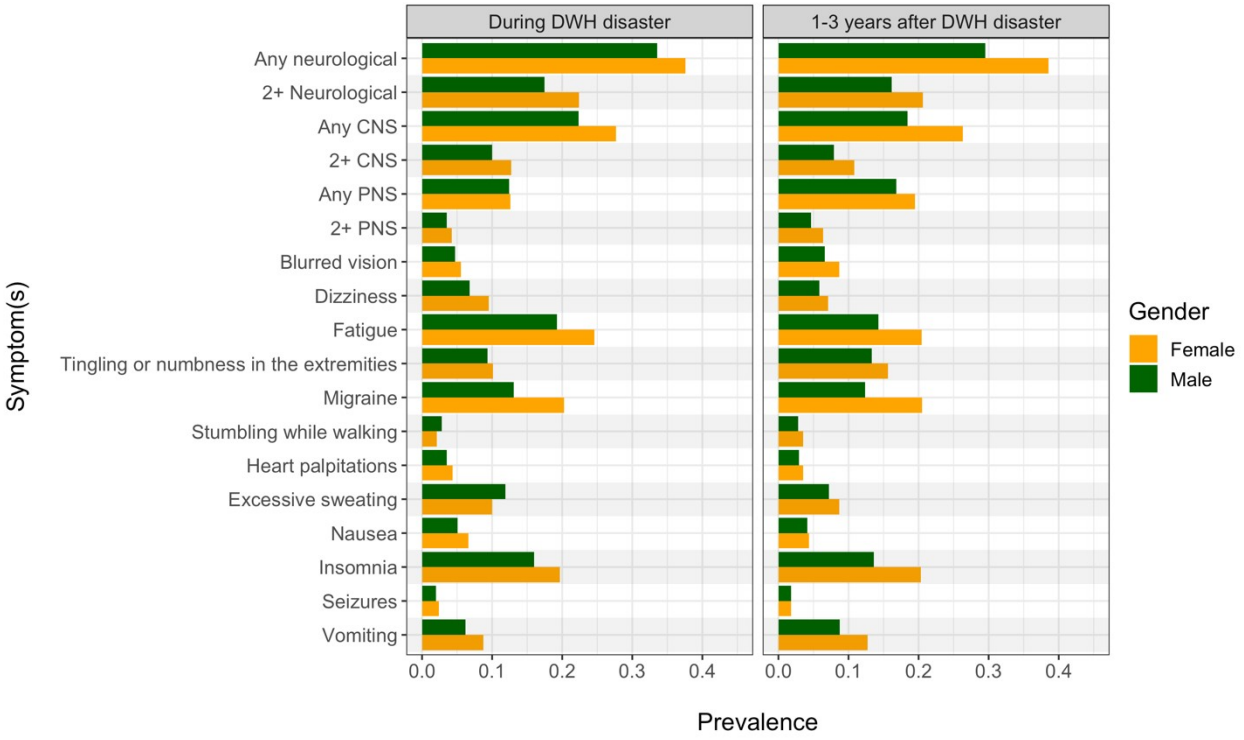

Figure A3. Prevalence of the outcomes (individual symptoms and aggregate outcomes) experienced during the *DWH* disaster (denominator n=9,044) and 1-3 years after the *DWH* disaster (denominator n=9,274), by gender (male, female). Data on insomnia, seizures and vomiting were not ascertained for all participants, thus a different denominator was used (during *DWH* disaster: seizure – 6,109; vomit – 6,106; insomnia – 6,040; 1-3 years after disaster: seizure - 6,110; vomit – 6,121; insomnia – 4,701). CNS (central nervous system) symptoms include dizziness, sweating, palpitations, nausea, and migraine. PNS (peripheral nervous system) symptoms include tingling or numbness in extremities, blurred vision, and stumbling.

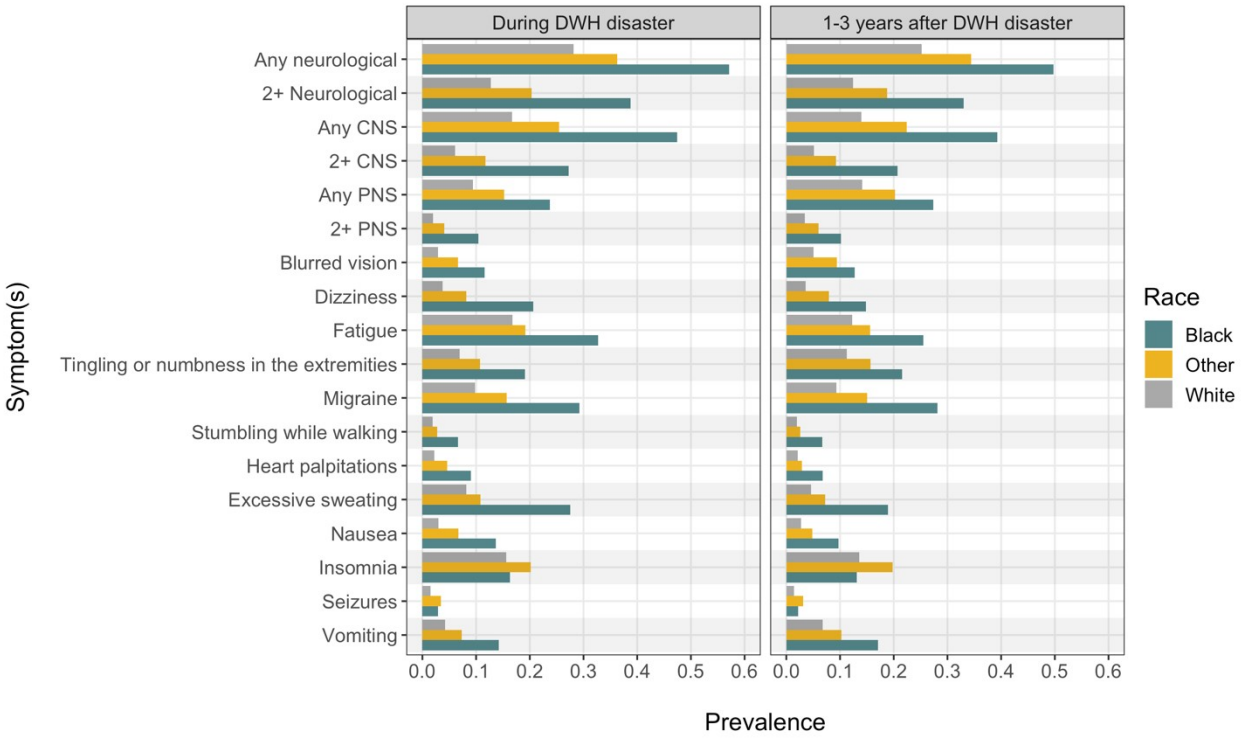

Figure A4. Prevalence of the outcomes (individual symptoms and aggregate outcomes) experienced during the *DWH* disaster (denominator n=9,044) and 1-3 years after the *DWH* disaster (denominator n=9,274), by self-identified race (Black, White, Other). Data on insomnia, seizures and vomiting were not ascertained for all participants, thus a different denominator was used (during *DWH* disaster: seizure – 6,109; vomit – 6,106; insomnia – 6,040; 1-3 years after disaster: seizure - 6,110; vomit – 6,121; insomnia – 4,701). CNS (central nervous system) symptoms include dizziness, sweating, palpitations, nausea, and migraine. PNS (peripheral nervous system) symptoms include tingling or numbness in extremities, blurred vision, and stumbling.

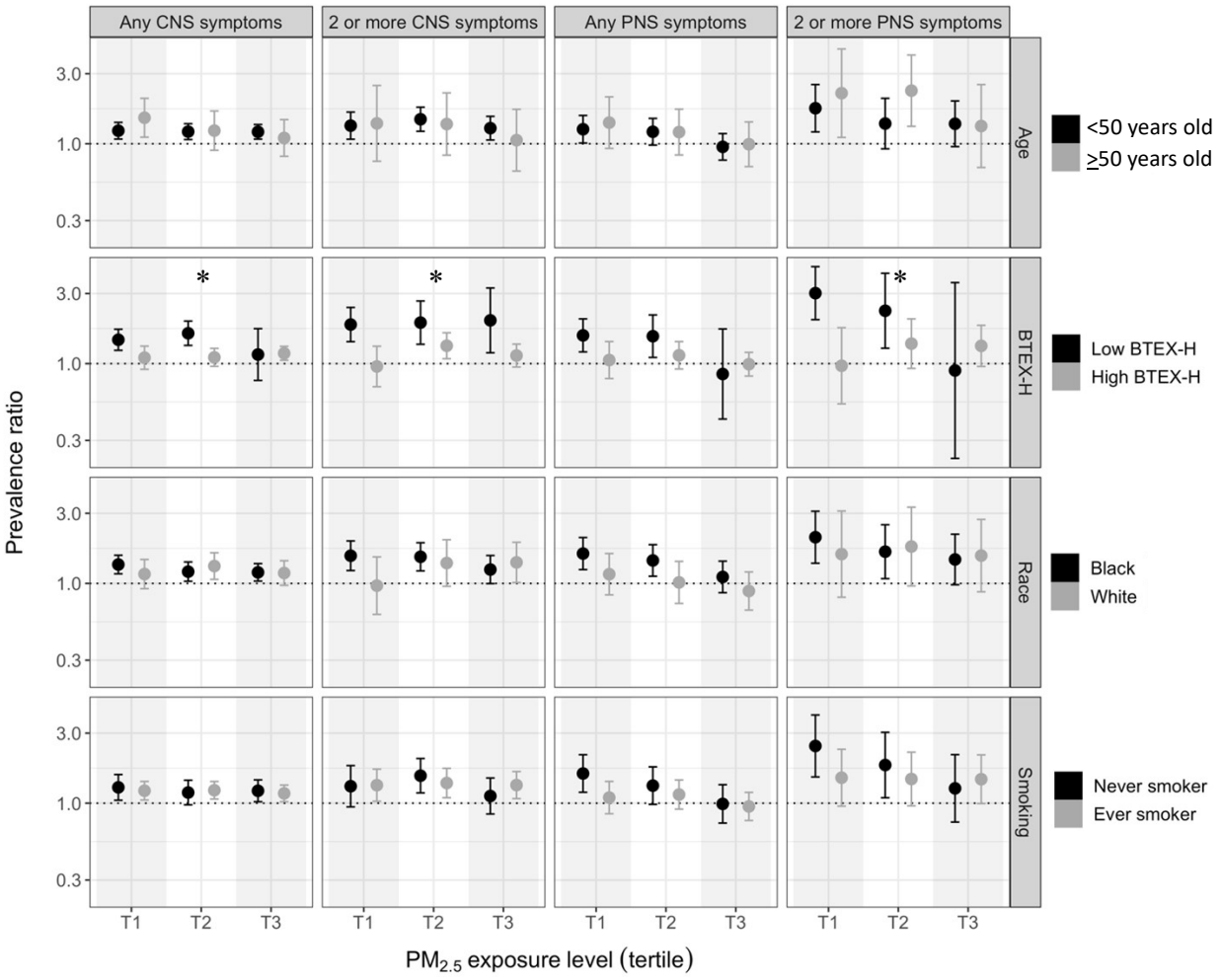

Figure A5. Prevalence ratios and 95% confidence limits for the relationship between tertiles of cumulative $PM_{2.5}$ exposure for exposed individuals (T1, n=588, $PM_{2.5}$: 10-679 µg/m^3-days; T2, n=602, $PM_{2.5}$: 689-1378 µg/m^3-days; T3, n=779, $PM_{2.5}$: 1406-4071 µg/m^3-days) compared to on-water workers with the lowest exposure (n=7026, $PM_{2.5}$<1 µg/m^3-days) and central (CNS) or peripheral (PNS) nervous system symptoms during the *DWH* disaster, stratified by (separately) age (< 50 vs. ≥50 years old); spill-related benzene, toluene, ethylbenzene, xylene and n-hexane (ppb-days; *low*=below median, *high*=above median); race (Black, White, Other [not shown]); and smoking status (never/ever). Models were adjusted for age (< 50 vs. ≥50 years old), quartiles of BTEX-H exposure (ppb-days) and race (White, Black, Other), except when that was the variable for stratification. CNS symptoms include dizziness, sweating, palpitations, nausea, and migraine. PNS symptoms include tingling or numbness in extremities, blurred vision, and stumbling. *Likelihood ratio test comparing the main model to stratified models, p<0.05

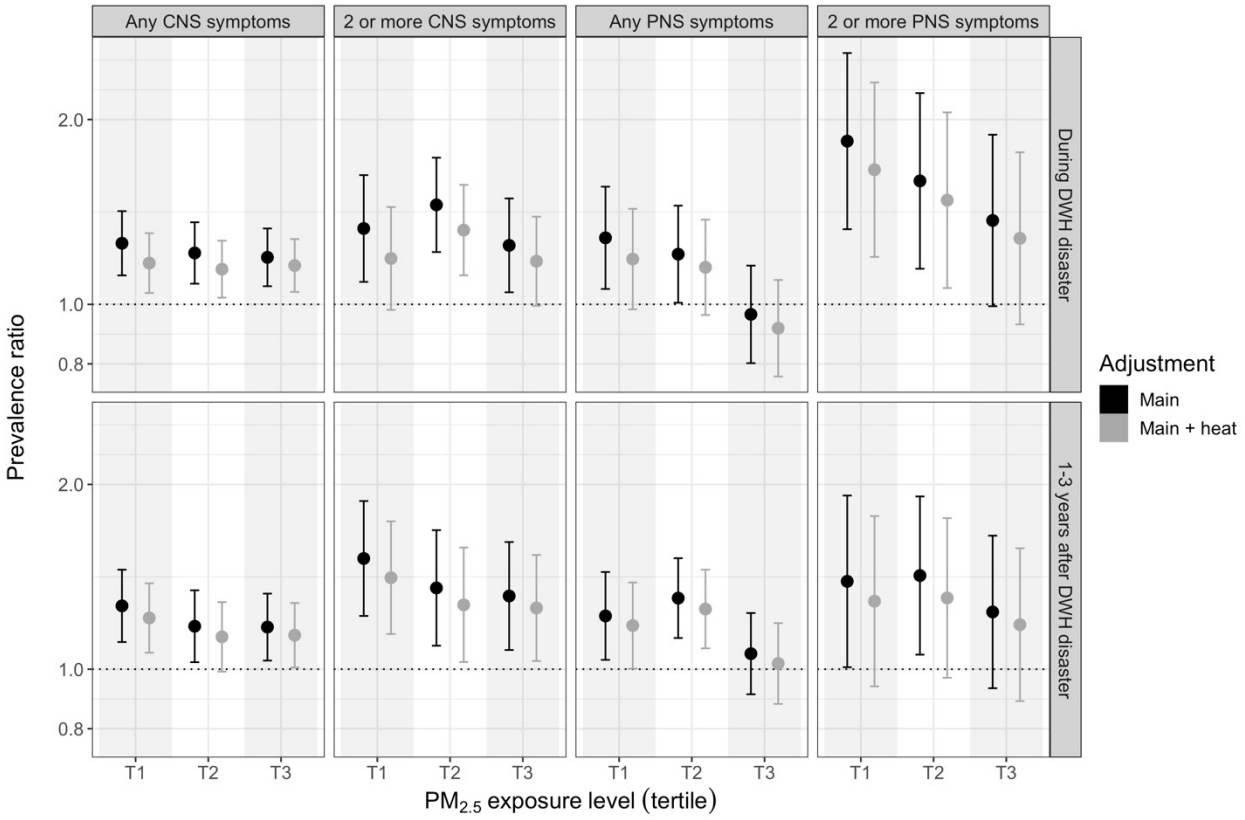

Figure A6. Prevalence ratios and 95% confidence limits for the relationship between tertiles of cumulative $PM_{2.5}$ exposure for exposed individuals (T1, n=588, $PM_{2.5}$: 10-679 µg/m^3-days; T2, n=602, $PM_{2.5}$: 689-1378 µg/m^3-days; T3, n=779, $PM_{2.5}$: 1406-4071 µg/m^3-days) compared to on-water workers with the lowest exposure (n=7026, $PM_{2.5}$<1 µg/m^3-days) and central (CNS) or peripheral (PNS) nervous system symptoms. The main adjustment set includes age (< 50 vs. ≥50 years old), race (Black, White, Other), and quartiles of spill-related benzene, toluene, ethylbenzene, xylene and n-hexane (ppb-days); some models were additionally adjusted for heat exposure. CNS symptoms include dizziness, sweating, palpitations, nausea, and migraine. PNS symptoms include tingling or numbness in extremities, blurred vision, and stumbling. *Likelihood ratio test comparing the main model to stratified models, p<0.05

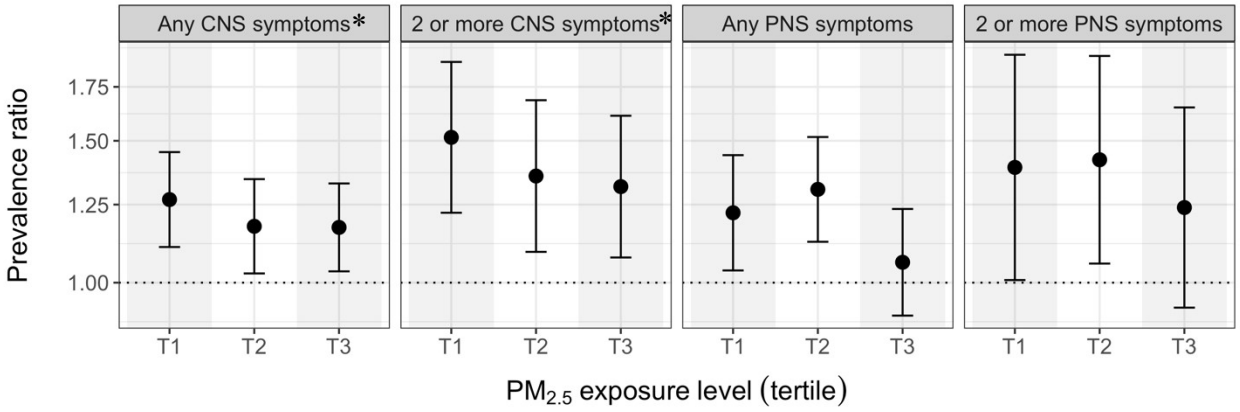

Figure A7. Prevalence ratios and 95% confidence limits for the relationship between tertiles of cumulative $PM_{2.5}$ exposure for exposed individuals (T1, n=606, $PM_{2.5}$: 10-679 µg/m^3-days; T2, n=618, $PM_{2.5}$: 689-1378 µg/m^3-days; T3, n=801, $PM_{2.5}$: 1406-4071 µg/m^3-days) compared to on-water workers with the lowest exposure (n=7201, $PM_{2.5}$<1 µg/m^3-days) and central (CNS) or peripheral (PNS) nervous system symptoms 1-3 years after the *DWH* disaster. Models were adjusted for age (< 50 vs. ≥50 years old), race (Black, White, Other), and quartiles of spill-related benzene, toluene, ethylbenzene, xylene and n-hexane (ppb-days). CNS symptoms include dizziness, sweating, palpitations, nausea, and migraine; PNS symptoms include tingling or numbness in extremities, blurred vision, and stumbling. *Test of trend with a p-value <0.05.

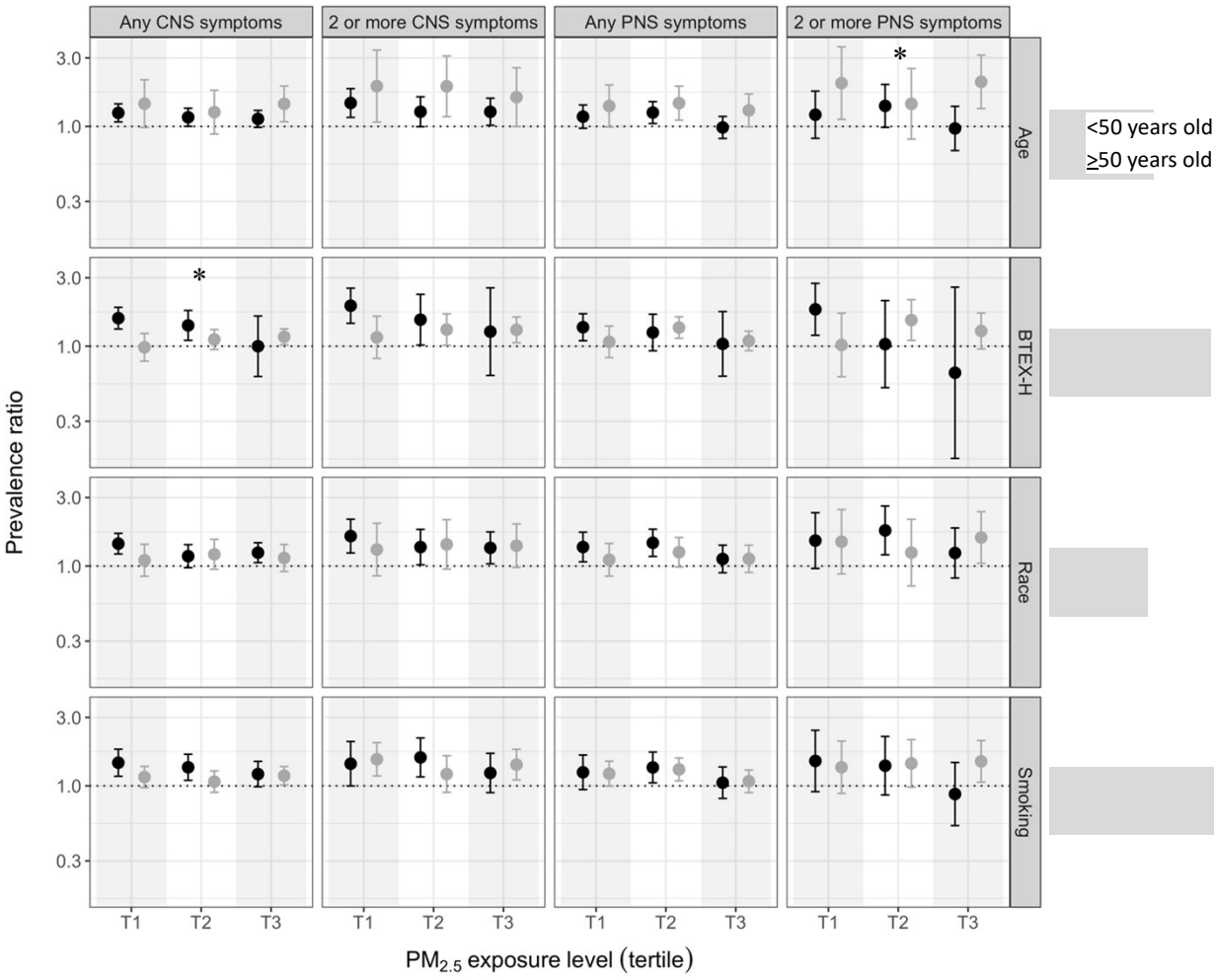

Figure A8. Prevalence ratios and 95% confidence limits for the relationship between tertiles of cumulative $PM_{2.5}$ exposure for exposed individuals (T1, n=606, $PM_{2.5}$: 10-679 µg/m^3-days; T2, n=618, $PM_{2.5}$: 689-1378 µg/m^3-days; T3, n=801, $PM_{2.5}$: 1406-4071 µg/m^3-days) compared to on-water workers with the lowest exposure (n=7201, $PM_{2.5}$<1 µg/m^3-days) and central (CNS) or peripheral (PNS) nervous system symptoms 1-3 years after the *DWH* disaster, stratified by (separately) age (< 50 vs. ≥50 years old); spill-related benzene, toluene, ethylbenzene, xylene and n-hexane (ppb-days; *low*=below median, *high*=above median); race (Black, White, Other [not shown]); and smoking status (never/ever). Models were adjusted for age (< 50 vs. ≥50 years old), quartiles of BTEX-H exposure (ppb-days) and race (White, Black, Other), except when that was the variable for stratification. CNS symptoms include dizziness, sweating, palpitations, nausea, and migraine; PNS symptoms include tingling or numbness in extremities, blurred vision, and stumbling. *Likelihood ratio test comparing the main model to stratified models, p<0.05.

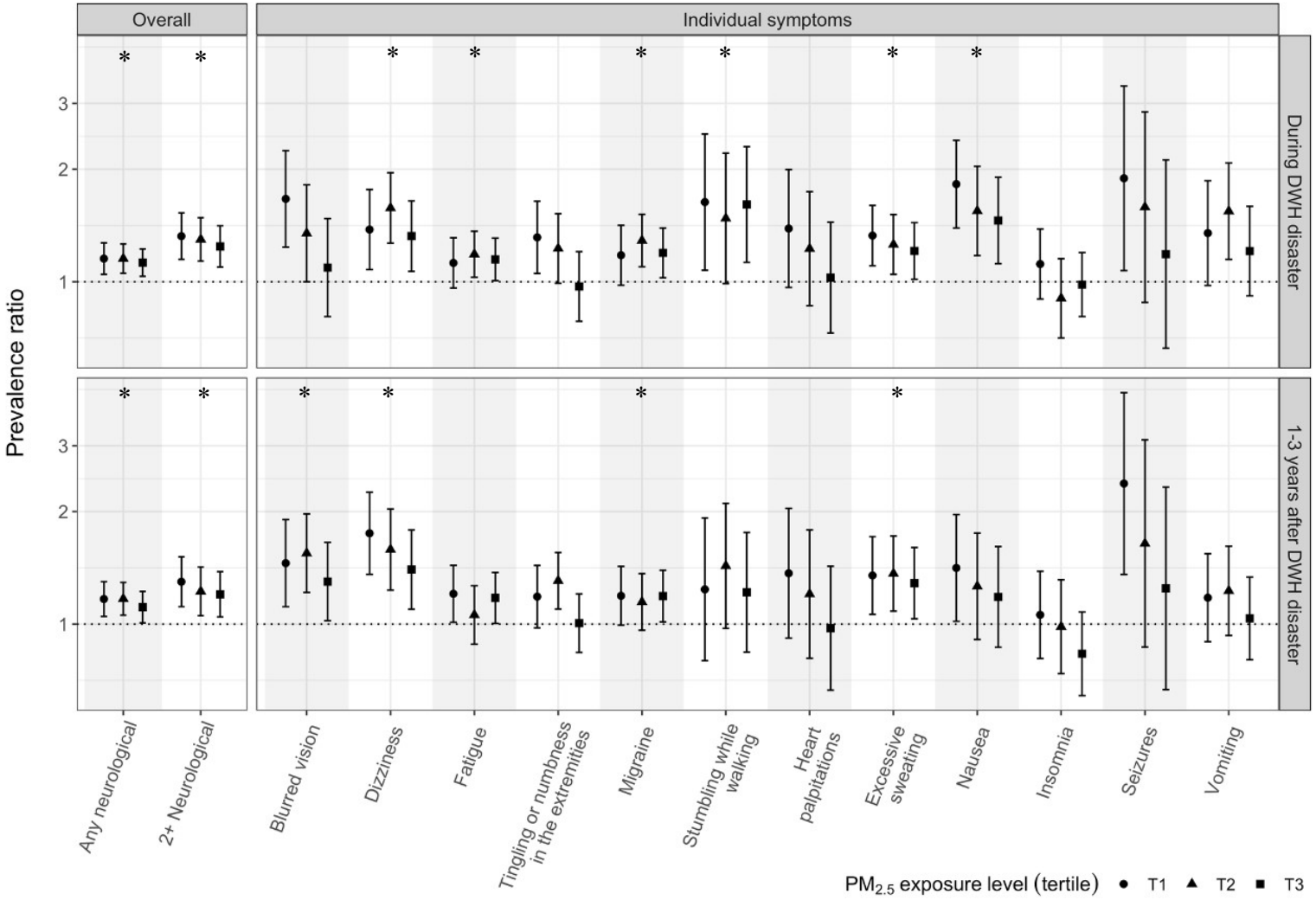

Figure A9. Prevalence ratios and 95% confidence limits for the relationship between tertiles of cumulative $PM_{2.5}$ exposure for exposed individuals (T1, $PM_{2.5}$: 10-679 μg/m^3-days; T2, $PM_{2.5}$: 689-1378 μg/m^3-days; T3, $PM_{2.5}$: 1406-4071 μg/m^3-days) compared to on-water workers with the lowest exposure ($PM_{2.5}$<1 μg/m^3-days) and neurological symptoms. Models were adjusted for age (< 50 vs. ≥50 years old), race (Black,

White, Other), and quartiles of disaster-related benzene, toluene, ethylbenzene, xylene and n-hexane (ppb-days). *Test of trend with a p-value of <0.05.