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Mental Health Indicators Associated with the 2010 *Deepwater Horizon* Oil Spill: A Cross-Sectional Analysis of the GuLF STUDY

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Summary

Background—Adverse mental health effects were reported following oil spills but few studies identified specific responsible attributes of the clean-up experience.

Methods—We evaluated the impact of multiple oil spill response and clean-up (OSRC) exposures following the *Deepwater Horizon disaster* on the mental health using data from the GuLF STUDY which includes 8,968 workers and 2,225 non-workers who completed an exam with depression and post-traumatic stress (PTS) screeners.

Findings—OSRC work was associated with increased prevalence of depression, $PR_{\text{Depression}}=1.22$ (1.08, 1.37) and PTS, $PR_{\text{PTS}}=1.35$ (1.07, 1.71). Among workers, those who reported smelling oil, dispersants or cleaning chemicals had an elevated prevalence of depression, $PR_{\text{Depression}}=1.58$ (1.38, 1.81) and PTS, $PR_{\text{PTS}}=2.29$ (1.71, 3.07). Other factors associated with depression and PTS included stopping work because of the heat ($PR_{\text{Depression}}=1.36$ [1.22, 1.52] and $PR_{\text{PTS}}=1.41$ [1.14, 1.74]) and working as a commercial fisherman prior to the spill ($PR_{\text{Depression}}=1.36$ [1.19, 1.56]; $PR_{\text{PTS}}=1.86$ [1.46, 2.38]). Increasing exposure to total hydrocarbons (TH) appeared associated with depression and PTS but after taking into account work experiences, only the association between the highest TH level and PTS remained, $PR_{\text{PTS}}=1.75$ (1.11, 2.76).

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Contributors

RKK, LSE, and DPS designed the study and directed its implementation, including quality assurance and control. RKK, JAM, WBJ II, and JP conducted the data analysis. RKK, SRL, LSE, JAM, SG and DPS interpreted the results and suggested additional analyses as appropriate. RKK and SRL wrote the manuscript draft and all authors contributed revisions. MDC oversaw the data collection including quality assurance and control. All authors have reviewed the manuscript and approve of the version to be published.

Declaration of Interests:

The authors declare that they have no actual or potential competing financial interests.

Interpretation—Workers with high levels of TH exposure or potentially stressful work experiences had increased prevalence of depression and PTS.

Background

The 2010 *Deepwater Horizon* oil spill (DHOS) disaster was the largest marine oil spill in U.S. history.¹ As suggested by prior studies of communities impacted by oil spills^{2,3} there were several characteristics of the spill that would suggest an increased risk for post-event psychological adversity among Gulf Coast residents. These included negative media coverage, severe harm to ecosystems and wildlife, disruption to local industries (e.g., fishing, oil and gas exploration, and tourism), uncertainty about the physical health effects of the oil and chemical dispersants, residential proximity to the oil spill, and prior experiences with disasters among those affected, including experiences with Hurricanes Katrina and Rita in 2005 and Hurricane Isaac in 2008.^{4–13}

Despite these risks, two existing studies of Gulf Coast residents documented few significant changes in mental health in the general population from pre- to post-spill.^{14,15} Several factors have been proposed that may have acted as potential buffers to a psychological effect of the event in the general population; centrally, there were minimal spill-related injuries and mortality, disruptions to vital services, and long-term economic impacts.¹⁶ However, there was substantial variability in post-spill mental health, with residents who experienced higher levels of physical exposure to oil during the oil spill or experiencing large financial impact at greater risk of adverse outcomes.¹² Individuals who participated in oil spill response and clean-up (OSRC) activities are a potentially high risk group.¹⁷ These workers repeatedly witnessed the vast effects of the DHOS on the environment and had direct contact with hazardous chemicals typically found in oil, chemical dispersants, and cleaning solutions such as benzene, toluene, ethylbenzene, xylene, 2-butoxyethanol, and propylene glycol, increasing risk for adverse health conditions (e.g., respiratory conditions, headaches)^{6,7} that, in turn, could be associated with poor mental health.^{7,18,19} Additionally, it is possible that the chemical exposures encountered through OSRC work may be neurotoxic and physical contact with these chemicals could have the potential to induce adverse mental health effects.²⁰

Two previous studies suggest that OSRC work increases risk for adverse mental health indicators. First, a study of the *Exxon Valdez* oil spill found higher prevalence of post-traumatic stress disorder (PTSD) and depression among residents, including OSRC workers, who were classified as highly exposed.²¹ Second, a community survey after the DHOS found higher PTSD symptoms among respondents employed in any of five occupations classified as “at-risk,” including oil rig work.²² However, these studies were conducted primarily among a much smaller sample of community members who tend to have less or no direct physical contact with oil. Furthermore, no study has evaluated the mental health risks of OSRC work from the DHOS. Disaster recovery work has been associated with elevated mental health risks in other contexts, including in the aftermath of the September 11 terrorist attacks.²³ Whether these results apply to oil spills, however, is not known.

This is the first study documenting the psychological impact of OSRC work from the DHOS. Both quantitative chemical exposures and qualitative experiences during OSRC work were investigated to determine any potential association with increased prevalence of PTS symptoms and depression. The types of OSRC jobs performed were also analyzed as a proxy for all exposures encountered during the spill in an effort to determine specific responsible attributes from the various OSRC jobs that may lead to negative mental health effects.

Methods

Data Collection and Sample

We used data from the Gulf Long-Term Follow-up Study (GuLF STUDY), a prospective cohort study of individuals 21 years and older who completed oil spill clean-up safety training and were either hired to perform OSRC work (workers), or weren't hired (non-workers) in 2010.²⁴ A detailed description of the GuLF STUDY can be found elsewhere.²⁴ Briefly, enrollment telephone interviews were collected between 2011 and 2013 about spill-related activities, demographics, lifestyle, and health. Extensive efforts were taken to encourage participation and minimize non-response including multiple contact attempts, on-the-ground locating, and mass media advertising campaigns. Within a few weeks after enrollment, participants from the five Gulf states (Alabama, Florida, Louisiana, Mississippi, and Texas) were invited to participate in a home visit where additional questionnaires, biological and environmental samples, and anthropometric/physiologic measurements were collected by trained staff who also obtained written informed consent. Participants received \$50 for completing the home visit. Data on mental health indicators were collected during the home visit and are used in the analyses presented. The Institutional Review Board of the National Institute of Environmental Health Sciences approved the GuLF STUDY protocol.

Outcomes

Two standardized mental health inventories shown to have strong validity and reliability in previous work were used.^{25,26} The Patient Health Questionnaire-8 (PHQ-8) contains eight questions which ask participants how many days they experienced symptoms of depression during the last two weeks. For each item, a value was assigned corresponding to the number of days participants reported symptoms: 0=0–1 days, 1=2–6 days, 2=7–11 days, and 3=12–14 days. The values for all items were summed to arrive at a total PHQ-8 score, with scores of ten or more suggesting a probable indication of moderate to severe depression, hereafter referred to as “depression” (Cronbach's $\alpha=0.90$).²⁷

Participants also completed the 4-item Primary Care PTSD Screener which indicated symptoms in the last month indicative of PTSD. These items were linked to the oil spill and clean-up activities. Positive responses to three or more questions suggest a probable indication of moderate to severe PTSD, hereafter referred to as “PTS” (Cronbach's $\alpha=0.76$).²⁶

Exposure

Participants who worked at least one day in support of the DHOS response were categorized as workers and detailed information about their jobs and tasks performed were obtained at enrollment. Workers encompassed a diverse group; some experienced direct contact with oil and related petrochemicals, while others worked in supportive roles such as information technology, transportation, and security. Non-workers trained to be part of the clean-up effort but were not hired.

Industrial hygienists created a job exposure matrix (JEM) based on quantitative ambient and personal monitoring measurements of volatile organic compounds collected at the time of the DHOS clean-up.²⁸ From this JEM, various jobs/tasks were assigned TH levels that could vary by time and location. Based on their questionnaire responses, worker exposures to TH could then be determined as a proxy for all petroleum based products encountered.²⁸ The present analysis used the maximum TH level for each worker, across all tasks and time periods.²⁸ Additionally, industrial hygienists classified participants into 6 OSRC job groups and also by likely exposure to burning oil.²⁸

The enrollment questionnaire asked workers about other OSRC experiences that were not necessarily highly correlated with TH exposure, but could have been stressful or related to other chemical and non-chemical exposures. These included whether they smelled oil, dispersants, or cleaning chemicals; their skin or clothing contacted oil, tar, or oily water; they ever stopped work due to the heat; their job involved handling oiled plants or wildlife; their body or clothing ever became wet with chemicals; their job involved handling dispersants; or they had worked as a commercial fisherman in the past (and presumably suffered employment disruption).

Covariates

Demographic and financial variables including age, gender, race, annual household income, marital status, employment status, and reported concern about paying bills since the DHOS were collected via questionnaire and included in the analysis. To distinguish between the effects of clean-up work and proximity to the spill more generally, a dichotomous indicator for whether or not participants resided in a county directly on or adjacent to the Gulf coast where oil appeared was included. Two other measures of potential susceptibility to spill related adverse mental health outcomes – prior mental health diagnosis and previous residential displacement by Hurricanes Isaac and/or Katrina were included in the analysis along with duration of time spent in OSRC work and prior oil industry experience.

Statistical Analysis

We used log binomial regression to compare the prevalence of depression and PTS a) first between workers versus non-workers (n=11,193), and b) among workers only (n=8,968), comparing those who differed in either potentially stressful OSRC experiences or exposure to TH. Separate analyses were made for depression vs. PTS. For the workers, we examined the 7 potentially stressful OSRC job experiences as exposures. We also examined 3 types of job related exposures (estimated maximum TH exposure, job type, and exposure to burning/flaring). Finally, we examined the 7 OSRC experiences as exposures while controlling for

maximum TH exposure. Log binomial regression calculates prevalence ratios (PR) to compare exposed and unexposed groups: PRs are less biased than odds ratios (produced by logistic regression) when predicting moderately prevalent health outcomes.²⁹ In preliminary models (not reported) we looked at the given exposures alone (e.g. worker vs. non-worker, or each of the 7 OSRC job experiences individually), in relation to each outcome, and then introducing the covariates in steps, to assess interrelationships. For the final models, we entered all covariates along with the exposures, to produce fully-adjusted PRs. Thus, there were 2 regressions (depression and PTS) for workers vs. non-workers. Among workers only, there were 2 regressions (depression and PTS) for the 7 OSRC job experiences entered simultaneously; 6 regressions for the 3 types of job-related exposures and each of the 2 outcomes (depression and PTS); and 2 regressions (depression and PTS) for the 7 OSRC job experiences (entered simultaneously) controlling for maximum TH exposure. Among workers there was also a series of regressions for sensitivity analyses, looking at each of the two outcomes for each of the 7 OSRC job experiences individually (14 regressions) in the listwise-deleted data, to compare with results from another 14 regressions conducted in larger datasets (not suffering from listwise deletion when considering the 7 OSRC job experiences individually rather than as a group).

Covariates were chosen to reflect basic demographic characteristics that could differ among comparison groups (sex, race, age, income, and proximity to Gulf/spill), as well as potentially stressful life circumstances (divorced/widowed/separated, unemployment, worrying about paying bills, displacement by Hurricanes Katrina or Isaac, or pre-existing mental health condition) that could account for group differences in depression or PTS. Duration of spill work was an additional covariate used in the worker-only analyses.

Participants missing any covariate (286 of 2,225 non-workers; 1,021 of 8,968 workers) were excluded from the worker vs. non-worker analyses, along with those missing either depression (67 non-workers; 334 workers) or PTS measures (25 non-workers; 122 workers). For the worker-only analyses, after excluding those who were missing a covariate (n=1,021) or key exposure variable (OSRC experiences, n=1,361; TH exposure n=132). There were 239 missing depression data, leaving 6,215 for depression analyses, and 88 missing PTS data, leaving 6,366 for PTS analyses. All analyses were conducted using SAS version 9.4 (Cary, NC).

Role of the Funding Source

This study was funded by the National Institutes of Health (NIH) Common Fund and the Intramural Research Program of the NIH, National Institute of Environmental Health Sciences (ZO1 ES 102945). These funding sources did not have any role in the study design, data collection, analysis, or interpretation of the data, nor the writing of the report and decision to submit this article for publication. RKK, JAM, SRL, LSE, WBJ II, MDC, and JP had access to the raw data. The corresponding author (RKK) had full access to all of the data and the final responsibility to submit for publication.

Results

The mean age was 43 years for workers and 47 years for non-workers (Table 1). Most workers (80%) and non-workers (71%) were men. Slightly over half of each group was white and 39% of workers and 44% of non-workers reported annual incomes \leq \$20,000.

After controlling for residential proximity to the Gulf of Mexico, age, gender, race, income, marital status, employment status, financial strain, displacement due to Hurricanes Katrina or Isaac, and pre-existing mental health conditions, the prevalence of depression was increased among those who did OSRC work compared to non-workers (Table 1, $PR_{Dep}=1.22$ (1.08,1.37)). The association was unchanged after controlling for other oil industry experience. In an adjusted model, PTS was also associated with OSRC work, $PR_{PTS}=1.34$ (1.06,1.69) and the association remained after controlling for other oil industry experience, $PR_{PTS}=1.35$ (1.07, 1.71).

Among workers, the median days of OSRC work was 93 days (range 1 – 1044) with an interquartile range of 60–182 days. After adjusting for both TH and stressful oil spill exposures, the prevalence of depression did not increase with increasing days worked. However, PTS was significantly increased with PR 1.02 (1.01, 1.04) for each 30-day increment.

Workers who reported smelling oil, dispersants or cleaning chemicals had increased adjusted prevalence of depression, $PR_{Dep}=1.56$ (1.37, 1.78) and PTS, $PR_{PTS}=2.25$ (1.71, 2.96) (Table 2). Other experiences associated with depression and PTS were having to stop work because of the heat ($PR_{Dep}=1.37$ (1.23, 1.53), $PR_{PTS}=1.41$ (1.15, 1.74)) and being a commercial fisherman ($PR_{Dep}=1.38$ (1.21, 1.57), $PR_{PTS}=2.01$ (1.58, 2.55)). Those who reported that their body or clothing ever became wet with chemicals had increased PTS, $PR_{PTS}=1.23$ (1.00, 1.51) but not depression, $PR_{Dep}=1.06$ (0.95, 1.18).

Increasing levels of TH also were associated with increasing prevalence of depression (TH 0.3–0.99 ppm: $PR_{Dep}=1.31$ (1.06, 1.60); TH 1.00–2.99 ppm: $PR_{Dep}=1.32$ (1.06, 1.63); TH \geq 3.00: $PR_{Dep}=1.44$ (1.15, 1.81)) and PTS (TH 0.3–0.99: $PR_{PTS}=1.29$ (0.84, 1.98); TH 1.00–2.99: $PR_{PTS}=1.63$ (1.05, 2.51); TH \geq 3.00: $PR_{PTS}=2.61$ (1.68, 4.05)) (Table 3).

When TH exposure and stressful work experiences were considered together, the association between the highest TH exposure level (\geq 3 ppm) and PTS was reduced but still significantly elevated, $PR_{PTS}=1.75$ (1.11, 2.76), but the association with depression was no longer apparent, $PR_{Dep}=1.07$ (0.84,1.36).

Workers were classified hierarchically (from highest likely TH exposure to lowest) according to the types of jobs/tasks they performed.²⁸ Elevated prevalence of depression was found for response work, $PR_{Dep}=1.44$ (1.03, 2.00); operations, $PR_{Dep}=1.71$ (1.23, 2.36); and decontamination tasks, $PR_{Dep}=1.45$ (1.05, 2.01) (Table 3). Job types were not significantly associated with PTS. However, exposure to burning or flaring of the oil was associated with PTS, $PR_{PTS}=1.37$ (1.05, 1.80), but not depression. After potential OSRC stressors were added into the models, these associations were no longer significant, though the association between burning/flaring oil and PTS was suggestive, $PR_{PTS}=1.21$ (0.92, 1.59).

Potentially stressful experiences such as smelling oil, dispersants, or cleaning chemicals, having to stop working due to the heat, or having worked as a commercial fisherman before the spill (which indicates the potential loss of livelihood due to the spill), were not highly correlated with exposure to TH (Appendix 1). Furthermore, the associations between potentially stressful work experiences and mental health effects remained after adjusting for TH exposure (Appendix 2).

Comparison of those who were included and excluded from the analysis revealed no meaningful differences although some comparisons were statistically significant (Appendix 3). Demographic and stress characteristics between those with and without depression or PTS symptoms are also presented (Appendix 4). As expected, participants with stressors such as unemployment, financial worries, and being displaced by Hurricane Isaac or Katrina scored positively for depression and PTS.

Sensitivity analyses comparing results for single exposure models, produced nearly identical results using the reduced analysis sample and the larger sample obtained when not restricted to participants with data on all stressors and exposures. For depression, this increased the sample size to $n=7,282$ to $7,628$ depending in the exposure of interest. For PTS, the sample size ranged from $n=7,491$ to $7,840$. This increase in sample size increased statistical power slightly, tightening confidence intervals, but point estimates were largely unchanged (Appendix 5 & 6). Isolating workers with only depression, only PTS, and those with both to determine whether there might be differential associations for the 7 OSRC job experiences yielded largely similar results presented in the main analysis (Appendix 7).

Discussion

This is the first study to document the impact of DHOS OSRC work on the mental health of workers. We found that participants who engaged in clean-up work had significantly higher prevalence of both depression and PTS, even when accounting for demographic characteristics and other predictors of post-disaster mental health, including preexisting mental health conditions, residential proximity to the oil spill in the Gulf of Mexico, and prior disaster experience.

Overall, the results provide evidence that the DHOS had significant mental health consequences for OSRC workers, mainly attributed to their work experiences. These findings are consistent with those of prior studies suggesting, but not explicitly demonstrating, mental health consequences associated with oil spill clean-up work.^{21,22} In contrast to these studies, which either used participating in clean-up work as the only indicator of spill exposure,²¹ or studied community members whose occupations were likely affected by the spill,²² we examined the independent effects of various aspects of clean-up work on key mental health indicators, providing evidence that different activities confer unique mental health risks. These findings also contribute to the broader literature on disaster response by showing that the response associated risks observed in other contexts (e.g., in the aftermath of 9/11)²³ extend to oil spill disasters.

This study is the result of extensive efforts to identify and recruit a large sample of DHOS clean-up workers – significantly larger than prior studies. These efforts provide greater confidence that the results reflect the mental health impact of clean-up work in the larger population than if we had explored this phenomenon through other methods (e.g. convenience or community-based sampling). The comparison group of residents who had completed clean-up safety training but who did not go on to participate the clean-up, rule out the interpretation that the significant associations observed here were due to preexisting differences that might make residents more or less likely to seek out clean-up work opportunities.

In light of these strengths, the results of this study have potentially important clinical and research implications. First, they suggest the importance of screening clean-up workers for mental health symptoms and connecting them with services, as well as the need for empirically supported interventions to reduce depression and PTS symptoms among this group. Primary care and other medical providers treating clean-up workers should be aware of the potential mental health consequences of clean-up activities, evaluate such consequences, and provide appropriate referrals as needed. Second, they provide a rationale for future studies that explore the particular aspects of clean-up work that confer mental health risks, factors that could mitigate or exacerbate the effects of clean-up work, and processes through which clean-up activities could lead to adverse outcomes.

Limitations

The findings should be interpreted in view of limitations of this study. First, despite the substantial efforts to recruit all potential workers, only 42% of those eligible completed a home visit and thus the mental health assessments. However, there were few demographic and health differences between eligible Gulf state residents who completed the telephone enrollment interview and those who completed the home visit.²⁴ Similarly, there were few meaningful differences between those included and excluded in this analysis and sensitivity analyses produced nearly identical results for single exposure models based on the study sample and a less restrictive one. Second, it is possible that there were systematic differences between the residents who completed safety training and were paid to participate in clean-up work and those who did not. For example, there could have been a “healthy worker” effect whereby workers were in better physical and mental health than non-workers at baseline. Not all such potential differences could be evaluated using data collected. However, since the analyses focused on OSRC exposures and experiences among workers only, the results are internally consistent. Furthermore, if there were a “healthy worker” effect, this would have biased the results toward finding no mental health impact of clean-up work and therefore does not directly challenge our results.

Third, mental health status was based on interviewer-administered screening instruments and not a clinical assessment. The American Psychiatric Association revised the PTS diagnostic criteria in the fifth edition of its Diagnostic and Statistical Manual of Mental Disorders (DSM-5;³⁰) and Criterion A requires either, “direct exposure, witnessing the trauma, ... or indirect exposure to aversive details of the trauma, usually in the course of professional duties”³⁰ of which workers in the GuLF STUDY would qualify as part of their professional

duties. Although these scales are intended to be a screener and are no substitute for clinical assessments, their use is normative and validated in large epidemiological studies.^{26,27} Fourth, retrospective reports of pre-spill mental health and prior disaster experience could have been influenced by post-spill mental health, inflating associations between them. However, these potentially inflated associations would have biased the analyses towards the null, making them less of a concern.

Despite these limitations, this is the first study to investigate the mental health effects of clean-up work in the aftermath of the DHOS. We documented that clean-up work was significantly associated with higher prevalence of moderate to severe depression and PTSD, and that these findings held when controlling for other known risk factors, such as preexisting mental health conditions and prior disaster exposure. Furthermore, among DHOS clean-up workers, the experience of the OSRC work proved to be more traumatic than exposure to the oil, dispersants, and cleaning chemicals itself (as measured by TH exposure). These findings provide further evidence that clean-up work is associated with adverse psychological consequences and pre-screening and post-event services may be needed to address workers' mental health needs when the next disaster inevitably strikes.

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Appendix

Appendix 1

Correlation Between TH level and Oil Spill Response and Clean-up Experience

	Smelled Oil	Clothing in Contact with oil	Stop work due to Heat	Oily Wildlife/Plants	Body Wet with Chemicals	Work with Dispersants	Work as Commercial Fisherman	TH 3 ppm	TH 1-0 – 2-9 ppm	TH 0-3 – 0-99 ppm	TH < 0-3 ppm
Smelled Oil	1-00										
Skin/Clothing in contact with oil	0-32	1-00									
Stop Working due to Heat	0-15	0-27	1-00								
Oily Wildlife/Plants	0-08	0-25	0-15	1-00							
Body wet with Chemicals	0-33	0-36	0-18	0-08	1-00						
Work with Dispersants	0-16	0-19	0-12	0-09	0-18	1-00					
Work as Commercial Fisherman	0-11	0-02	-0-04	-0-22	0-04	-0-04	1-00				
TH 3 ppm	0-15	0-14	0-07	-0-04	0-17	0-38	0-03	1-00			
TH 1-0 – 2-9 ppm	0-12	0-08	-0-02	-0-19	0-10	-0-03	0-24	-0-31	1-00		
TH 0-3 – 0-99 ppm	-0-14	-0-04	0-01	0-23	-0-13	-0-17	-0-17	-0-35	-0-58	1-00	
TH < 0-3 ppm	-0-14	-0-21	-0-08	-0-04	-0-15	-0-13	-0-13	-0-15	-0-25	-0-29	1-00

Appendix 2

Depression and PTS Associated With Oil Spill Response and Clean-up Experiences, Adjusted for Level of TH Exposure (Workers Only)

Predictor	Prevalence Ratio* (95% CI**)			
	Depression (n=6,215)		PTS (n=6,366)	
Smelled oil, dispersants, or cleaning chemicals	1-57	(1-38, 1-78)	2-19	(1-66, 2-88)
Skin/clothing in contact with oil/tar/oily water	1-04	(0-91, 1-20)	1-14	(0-86, 1-51)
Had to stop working due to heat	1-36	(1-22, 1-52)	1-40	(1-14, 1-72)
Job involving oily wildlife/plants/animals	0-95	(0-85, 1-05)	1-19	(0-97, 1-47)
Body/clothing ever became wet with chemicals	1-06	(0-96, 1-18)	1-20	(0-98, 1-48)
Any self-reported work with dispersants	1-06	(0-92, 1-21)	0-99	(0-78, 1-26)
Worked as a commercial fisherman	1-40	(1-23, 1-60)	1-97	(1-54, 2-50)

* Adjusted for age, sex, race, annual household income, marital status, employment status, financial worries, displaced by Hurricanes Isaac or Katrina, mental health diagnosis prior to the spill, other oil industry experience, duration of clean-up work, TH exposure level.

** CI denotes confidence interval.

Appendix 3

Comparison of Workers Included and Excluded from Analyses

Variable	Analysis N	Included subjects (6,215)	Excluded subjects (2,753)
Female sex (%)	8,968	19-4	21-4
African American (%)	8,938	37-2	30-0

Variable	Analysis N	Included subjects (6,215)	Excluded subjects (2,753)
Divorced/Separated/Widowed (%)	8,943	23.6	21.9
Financial worries (%)	8,910	54.5	53.8
Other oil industry experience (%)	8,949	16.6	17.4
Max estimated TH exposure (%)			
0-29 ppm	8,929	11.2	23.0
0.3 to 0.99 ppm		39.6	30.3
1.00 to 2.99 ppm		33.8	29.9
3.0 ppm		15.5	13.6
Age: Mean (SD)	8,966	42.8 (12.8)	44.1 (13.0)
Duration of spill work: Mean (SD)	8,968	146.0 (142.4)	144.3 (150.3)

Appendix 4

Comparison of Workers with and without Depression, PTS Symptoms

Variable	Depression (N = 6,215)			PTS (N = 6,366)		
	Yes	No	p-value	Yes	No	p-value
Female sex (%)	24.0	18.4	0.0001	20.1	19.6	0.8143
Age 60 or more (%)	4.9	11.2	0.0001	6.3	10.4	0.0118
Age: Mean (SD)	42.6 (11.2)	42.8 (13.1)	0.5317	43.5 (11.5)	42.8 (12.9)	0.2602
African American (%)	39.0	36.8	0.1711	46.4	36.3	0.0001
Household Income (%)						
<= \$20,000	48.8	38.9	0.0001	48.0	40.1	0.0003
\$20,001 – \$50,000	35.0	34.1		35.1	34.5	
>\$50,000	16.2	26.9		16.9	25.5	
Unemployed (%)	62.5	40.8	0.0001	63.1	43.6	0.0001
Divorced/Separated/Widowed (%)	29.7	22.3	0.0001	29.3	23.2	0.0066
Financial worries (%)	76.3	49.9	0.0001	78.9	53.2	0.0001
Pre-existing Mental Health Condition (%)	30.6	14.8	0.0001	25.3	17.1	0.0001
Displaced by Hurricane Isaac or Katrina (%)	25.9	21.7	0.0026	35.4	21.7	0.0001
Other oil industry experience (%)	18.3	16.2	0.09	22.4	16.4	0.0023

Appendix 5

Association of Individual Oil Spill Experiences and Mental Health Outcomes in Expanded and Restricted Study Sample (Workers Only)

Predictor	Prevalence Ratio* (95% CI**)							
	Depression				PTS			
	All Participants [†] (n=7,282 to 7,628)		Final Analysis Sample ^{††} (n=6,215)		All Participants [†] (n=7,491 to 7,840)		Final Analysis Sample ^{††} (n=6,366)	
Smelled oil, dispersants, or cleaning chemicals	1.68	(1.50, 1.88)	1.71	(1.51, 1.93)	2.91	(2.28, 3.72)	2.80	(2.15, 3.64)
Skin/clothing in contact with oil/tar/oily water	1.37	(1.22, 1.54)	1.33	(1.17, 1.52)	1.86	(1.45, 2.37)	1.82	(1.40, 2.38)
Had to stop working due to heat	1.55	(1.40, 1.71)	1.49	(1.33, 1.66)	1.87	(1.54, 2.28)	1.67	(1.36, 2.05)
Job involving oily wildlife/plants/animals	1.02	(0.92, 1.13)	1.00	(0.90, 1.11)	1.14	(0.94, 1.38)	1.15	(0.93, 1.41)
Body/clothing ever became wet with chemicals	1.30	(1.18, 1.43)	1.30	(1.17, 1.44)	1.74	(1.44, 2.09)	1.73	(1.42, 2.11)
Any self-reported work with dispersants	1.19	(1.05, 1.35)	1.16	(1.02, 1.33)	1.34	(1.07, 1.68)	1.37	(1.09, 1.73)
Worked as a commercial fisherman	1.47	(1.31, 1.65)	1.46	(1.28, 1.66)	2.19	(1.77, 2.73)	2.19	(1.73, 2.77)

* Adjusted for age, sex, race, annual household income, marital status, employment status, financial worries, displaced by Hurricanes Isaac or Katrina, mental health diagnosis prior to the spill, other oil industry experience, duration of clean-up work, TH exposure level.

[†] Models not adjusted for other exposures. Individuals included whether or not they have data on other exposures

^{††} Models not adjusted for other exposures. Excluding observations missing stressor experiences.

** CI denotes confidence interval.

Appendix 6

Association of Individual Oil Spill Exposures and Mental Health Outcomes in Expanded and Restricted Study Sample (Workers Only)

Predictor	Prevalence Ratio* (95% CI**)							
	Exposure Effect Estimate	Depression		PTS				
		Final Analysis Sample [†] (N=6,134)	All Participants ^{††} (N=7,576)	Final Analysis Sample [†] (N=6,284)	All Participants ^{††} (N=7,788)			
TH exposure 3-0 ppm	1.44	(1.15, 1.81)	1.40	(1.15, 1.70)	2.61	(1.68, 4.05)	2.83	(1.93, 4.15)
TH exposure 1.00 – 2.99 ppm	1.32	(1.06, 1.63)	1.29	(1.08, 1.54)	1.63	(1.05, 2.51)	1.77	(1.22, 2.58)
TH exposure 0.3 – 0.99 ppm	1.31	(1.06, 1.60)	1.29	(1.09, 1.54)	1.29	(0.84, 1.98)	1.37	(0.94, 1.99)

Predictor	Prevalence Ratio* (95% CI**)			
	Depression		PTS	
	Final Analysis Sample [†] (N=6,134)	All Participants ^{††} (N=7,576)	Final Analysis Sample [†] (N=6,284)	All Participants ^{††} (N=7,788)
TH exposure < 0.3 ppm (reference)	-	-	-	-
<u>Job type</u>	(N=6,215)	(N=7,613)	(N=6,366)	(N=7,825)
Response	1.44 (1.03, 2.00)	1.40 (1.09, 1.80)	1.70 (0.94, 3.06)	2.02 (1.25, 3.27)
Operations	1.71 (1.23, 2.36)	1.60 (1.25, 2.05)	1.69 (0.94, 3.03)	2.07 (1.29, 3.34)
Clean-up on water	1.36 (0.96, 1.91)	1.31 (1.01, 1.71)	0.91 (0.48, 1.75)	1.16 (0.68, 1.98)
Decontamination	1.45 (1.05, 2.01)	1.41 (1.10, 1.80)	1.23 (0.68, 2.21)	1.37 (0.83, 2.23)
Clean-up on land	1.32 (0.95, 1.85)	1.30 (1.01, 1.68)	0.92 (0.50, 1.72)	1.07 (0.63, 1.80)
Support work (reference)	-	-	-	-
<u>Burning/Flaring</u>	(N=6,215)	(N=7,477)	(N= 6,366)	(N=7,685)
Exposure to burning/flaring	1.07 (0.91, 1.26)	1.07 (0.92, 1.26)	1.37 (1.05, 1.80)	1.51 (1.18, 1.94)
No exposure (reference)	-	-	-	-

Appendix 7

Non-overlapping versus Overlapping Depression and PTS Associated with Oil Spill Response and Clean-up Experiences (Workers Only)

Predictor	Prevalence Ratio* (95% CI**)					
	Depression without PTS [†] (N=5,804) n=816 with Depression		PTS without Depression [†] (N=5,100) n=112 with PTS		PTS with Depression [†] (N=5,236) n=248 with both	
Smelled oil, dispersants, or cleaning chemicals	1.47	(1.27, 1.70)	2.09	(1.26, 3.46)	2.57	(1.82, 3.62)
Skin/clothing in contact with oil/tar/oily water	1.09	(0.93, 1.28)	1.59	(0.92, 2.74)	0.94	(0.67, 1.32)
Had to stop working due to heat	1.35	(1.19, 1.53)	1.13	(0.77, 1.65)	1.84	(1.41, 2.40)
Job involving oily wildlife/plants/animals	0.91	(0.80, 1.04)	0.81	(0.54, 1.21)	1.22	(0.94, 1.57)
Body/clothing ever became wet with chemicals	1.06	(0.93, 1.20)	1.40	(0.95, 2.08)	1.24	(0.96, 1.60)
Any self-reported work with dispersants	0.97	(0.82, 1.15)	0.78	(0.47, 1.27)	1.32	(1.01, 1.74)
Worked as a commercial fisherman	1.43	(1.23, 1.68)	2.61	(1.66, 4.13)	2.02	(1.48, 2.76)

* Adjusted for age, sex, race, annual household income, marital status, employment status, financial worries, displaced by Hurricanes Isaac or Katrina, mental health diagnosis prior to the spill, other oil industry experience, duration of clean-up work, TH exposure level.

[†] Reference group has neither depression nor PTS symptoms.

** CI denotes confidence interval.

Research in context

Evidence before this study

Surprisingly little is known about the potential health effects of exposures from oil spills. A Medline search of peer reviewed publications from January 1, 1955 to March 1, 2017 under the search terms “oil spill,” “human health effects,” “mental health,” “depression,” “PTSD,” “disaster response,” and “petroleum” yielded only eight spills that were studied for health effects among affected community members or response workers, despite the fact that there have been more than 38 major oil tanker spills since 1970. While we reviewed all published studies, we focused on prospective studies conducted around the oil spills of the *Exxon Valdez*, *Hebei Spirit*, *Prestige*, and *Deepwater Horizon*. Crude oil contains a number of components known to be toxic to human health. The *Deepwater Horizon* oil spill was unprecedented in size and duration and response activities involved exposure to oil, combustion products, chemicals in dispersants and cleaning solutions, and a range of physical and psychological stressors that could affect health. While previous studies following other oil spills, such as the *Exxon Valdez*, indicated increased risk for psychological health effects, it is not clear whether this effect is from direct chemical exposure or from non-chemical oil spill experiences.

Added value of this study

We conducted the first study documenting the psychological impact of oil spill response and clean-up work from the *Deepwater Horizon* oil spill. We used data from more than 6,200 individuals in the GuLF STUDY, which is considerably larger than all prior studies, to investigate whether quantitative exposures and experiences during oil spill response and clean-up work were associated with increased prevalence of depression and PTS. Including quantitative exposure measures at the individual level is also a considerable advance from prior studies.

Implications of all the available evidence

We found that participants who engaged in clean-up work had significantly higher prevalence of both depression and PTS, even when accounting for demographic characteristics and other predictors of post-disaster mental health, including preexisting mental health conditions, residential proximity to the oil spill in the Gulf of Mexico, and prior disaster experience. Potentially stressful experiences such as smelling oil, dispersants, or cleaning chemicals, having to stop working due to the heat, or having worked as a commercial fisherman before the spill (which indicates the potential loss of livelihood due to the spill), were especially influential. These findings provide further evidence that clean-up work is associated with adverse psychological consequences and suggest the need for pre-screening and post-event services to treat workers' mental health needs when the next disaster inevitably strikes.

Table 1

Characteristics of Workers and Non-Workers, GuLF STUDY Home Visit Participants, n (%)

Characteristic	Workers (N=8,968)		Non-Workers (N=2,225)	
	N	%	N	%
Age 60+ years	948	(11)	368	(17)
Age at enrollment -- Mean (SD)	43	(13)	47	(13)
Female sex	1,794	(20)	647	(29)
Race				
White	4,911	(55)	1,195	(54)
Black	3,125	(35)	756	(34)
Asian	47	(1)	29	(1)
Other	596	(7)	154	(7)
Other / Multi-racial	259	(3)	74	(3)
Income				
\$20,000	3,266	(39)	899	(44)
\$20,001 to \$50,000	2,829	(34)	632	(31)
> \$50,000	2,260	(27)	511	(25)
Unemployed at time of home visit	3,818	(44)	980	(45)
Separated or divorced or widowed	2,063	(23)	547	(25)
More worried about paying bills since spill	4,837	(54)	1,165	(53)
Pre-existing mental health condition	1,564	(18)	503	(23)
Displaced by Hurricane Isaac or Katrina	1,978	(23)	493	(23)
Other oil industry experience	1,507	(17)	367	(17)
Duration of spill work in days -- Mean (SD)	145	(145)	-	-
Skin/clothing exposed to oil, tar, oily water	5,466	(63)	-	-
Smelled oil, dispersants, or cleaning chemicals	4,722	(56)	-	-
Ever had to stop working because of heat	3,632	(43)	-	-
Job involved oily wildlife, plants, animals	3,425	(39)	-	-
Body/clothing ever became wet with chemicals	2,696	(31)	-	-
Any self-reported work with dispersants	1,156	(14)	-	-
Worked as a commercial fisherman	1,498	(17)	-	-
Maximum overall TH exposure			-	-
0-29 ppm	1,320	(15)	-	-
0.3 – 0.99 ppm	3,284	(37)	-	-
1.00 – 2.99 ppm	2,994	(34)	-	-
3.0 ppm	1,331	(15)	-	-
Worker job type			-	-
Response work	1,680	(19)	-	-
Operations work	1,888	(21)	-	-
Clean-up on water work	1,319	(15)	-	-
Decontamination work	1,794	(20)	-	-

Characteristic	Workers (N=8,968)		Non-Workers (N=2,225)	
	N	%	N	%
Clean-up on land work	1,462	(16)	-	-
Support work	825	(9)	-	-
Exposure to burning/flaring	823	(9)	-	-

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Table 2

Depression and PTS Associated with Oil Spill Response and Clean-up Experiences

Predictor	Prevalence Ratio* (95% CI**)			
	Depression (n=9,485)		PTS (n=9,739)	
Worked on the oil spill response and clean-up	1.22	(1.08, 1.37)	1.35	(1.07, 1.71)
	Workers only (n=6,215)		Workers only (n=6,366)	
Smelled oil, dispersants, or cleaning chemicals	1.56	(1.37, 1.78)	2.25	(1.71, 2.96)
Skin/clothing in contact with oil/tar/oily water	1.04	(0.91, 1.20)	1.17	(0.88, 1.55)
Had to stop working due to heat	1.37	(1.23, 1.53)	1.41	(1.15, 1.74)
Job involving oily wildlife/plants/animals	0.96	(0.87, 1.07)	1.17	(0.95, 1.44)
Body/clothing ever became wet with chemicals	1.06	(0.95, 1.18)	1.23	(1.00, 1.51)
Any self-reported work with dispersants	1.04	(0.92, 1.19)	1.15	(0.91, 1.45)
Worked as a commercial fisherman	1.38	(1.21, 1.57)	2.01	(1.58, 2.55)

* Adjusted for age, sex, race, annual household income, marital status, employment status, financial worries, displaced by Hurricanes Isaac or Katrina, mental health diagnosis prior to the spill, other oil industry experience, duration of clean-up work.

** CI denotes confidence interval.

Table 3

Depression and PTS Associated With Oil Spill Exposures (Workers Only)

Predictor	Prevalence Ratio* (95% CI**)			
	Depression (n=6,134)		PTS (n=6,284)	
	Covariates	Covariates and OSRC experiences	Covariates	Covariates and OSRC experiences
<u>Exposure Effect Estimate</u>				
TH exposure 3-0 ppm	1.44 (1.15, 1.81)	1.07 (0.84, 1.36)	2.61 (1.68, 4.05)	1.75 (1.11, 2.76)
TH exposure 1.00 – 2.99 ppm	1.32 (1.06, 1.63)	1.06 (0.85, 1.32)	1.63 (1.05, 2.51)	1.16 (0.75, 1.81)
TH exposure 0.3 – 0.99 ppm	1.31 (1.06, 1.60)	1.18 (0.96, 1.45)	1.29 (0.84, 1.98)	1.10 (0.72, 1.68)
TH exposure < 0.3 ppm (reference)	-	-	-	-
<u>Job type</u>				
Response	1.44 (1.03, 2.00)	0.94 (0.67, 1.33)	1.70 (0.94, 3.06)	0.71 (0.37, 1.33)
Operations	1.71 (1.23, 2.36)	1.19 (0.85, 1.65)	1.69 (0.94, 3.03)	0.69 (0.37, 1.30)
Clean-up on water	1.36 (0.96, 1.91)	1.00 (0.70, 1.42)	0.91 (0.48, 1.75)	0.44 (0.23, 0.87)
Decontamination	1.45 (1.05, 2.01)	1.13 (0.80, 1.58)	1.23 (0.68, 2.21)	0.58 (0.31, 1.10)
Clean-up on land	1.32 (0.95, 1.85)	1.18 (0.84, 1.65)	0.92 (0.50, 1.72)	0.57 (0.29, 1.09)
Support work (reference)	-	-	-	-
Exposure to burning/flaring	1.07 (0.91, 1.26)	0.97 (0.82, 1.15)	1.37 (1.05, 1.80)	1.21 (0.92, 1.59)
No exposure to burning/flaring (reference)	-	-	-	-

* Adjusted for age, sex, race, annual household income, marital status, employment status, financial worries, displaced by Hurricanes Isaac or Katrina, mental health diagnosis prior to the spill, other oil industry experience, duration of clean-up work.

** CI denotes confidence interval.