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Depression, Mental Distress and Domestic Conflict among Louisiana Women Exposed to the Deepwater Horizon Oil Spill in the WaTCH Study

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Short running title: Mental health and the Deepwater Horizon oil spill

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Abstract

Background: Psychological sequelae are among the most pronounced effects in populations following exposure to oil spills. Women in particular represent a vulnerable yet influential population, yet have remained relatively understudied with respect to the Deepwater Horizon Oil Spill (DHOS).

Objective: To describe the relationship between oil spill exposure and mental health among women living in the southern coastal Louisiana parishes affected by the DHOS.

Methods: The Women and Their Children's Health Study administered a telephone interview to a population-based sample of 2842 women between 2012 and 2014 following the DHOS. Participants were asked about depression, mental distress, domestic conflict and exposure to the oil spill.

Results: Over 28% of the sample reported symptoms of depression, 13% reported severe mental distress, 16% reported an increase in the number of fights with their partner, and 11% reported an increase in the intensity of partner fights. Both economic and physical exposure were significantly associated with depressive symptoms and domestic conflict, while only physical exposure was related to mental distress.

Conclusions: This large population-based study of women in southern coastal Louisiana, a particularly disaster-prone area of the country, revealed high rates of poor mental health outcomes. Reported exposure to the DHOS was a significant predictor of these outcomes, suggesting avenues for future disaster mitigation through the provision of mental health services.

Introduction

An explosion on the Deepwater Horizon drilling rig on April 20, 2010, killed 11 people and caused almost 5 million barrels of oil to flow into the Gulf of Mexico. The spill covered 68,000 square miles of land and sea and triggered a response effort involving the use of nearly 2 million gallons of dispersant chemicals (U.S. Coast Guard 2011). Considered the largest accidental marine oil spill in history, the Deepwater Horizon Oil Spill (DHOS) resulted in widespread environmental and economic damage, the exact nature of which is only beginning to be understood.

In the wake of the DHOS, the Institute of Medicine called for more research to generate evidence about the psychological and behavioral effects of oil spills (Institute of Medicine 2010). Previous disaster research has shown that psychological sequelae are among the most pronounced effects, with problems such as post-traumatic stress, depression, anxiety, and nonspecific distress, figuring prominently in the literature (Acierno et al. 2007; Adams et al. 2006; Amstadter et al. 2009; Cerdá et al. 2013; DiGrande et al. 2011; Galea et al. 2007; Galea et al. 2008; Norris et al. 2002; Ruggiero et al. 2009). Disasters involving oil spills specifically have resulted in emotional consequences to people who live in the vicinity and rely on the affected areas for their economic and nutritional livelihoods (Lyons et al. 1999). For example, one year after the 1989 Exxon Valdez Oil Spill (EVOS), higher prevalences of generalized anxiety, post-traumatic stress disorder (PTSD), and depression were observed among the highest exposed residents (Palinkas et al. 1993b). Individuals living in areas exposed to the 1996 Sea Empress oil spill were at higher risk of anxiety, depression, and worse mental health than individuals living in control areas (Lyons et al. 1999). Similarly, individuals exposed to the 2002 Prestige oil spill were also more likely to report suboptimal scores in mental health (Carrasco et al. 2007; Sabucedo et al. 2010).

Early observations of psychological and economic harm immediately following the DHOS have also been reported (Buttke et al. 2012; Osofsky et al. 2011), with striking similarities in resultant health effects noted between the DHOS and previous spills (Gill et al. 2012). A 2011 survey conducted by the Gulf State Population Survey (GSPS) demonstrated that direct exposure to the oil spill itself was the most important determinant of mental health (Fan et al. 2014).

Grattan(2011) observed that greater spill-associated income loss was associated with greater depression, anxiety, and other mental health outcomes. Gill (2012) found that Alabama residents with greater exposure to the oil, greater economic loss, and commercial ties to natural resources also experienced higher levels of psychological stress. Reports of anxiety disorder, 14 or more mentally unhealthy days in the previous month, and stress about having enough money to pay for housing or food were also high (Gill et al. 2012). A report on behavioral health following the DHOS documented an increase in major depressive episodes, thoughts of suicide, and suicide plans from pre- to post-oil spill among persons aged 18-25 years across the Gulf region (Substance Abuse and Mental Health Services Administration 2013). A study of female partners of oil spill clean-up workers revealed a higher prevalence of depression among those who had more physical contact with the oil, and an increase in the number of domestic partner fights among those with both greater physical contact and economic exposure to the DHOS (Rung et al. 2015).

Experiences of domestic conflict and interpersonal violence among women have been associated with hurricane disasters (Anastario et al. 2009; Harville et al. 2011; Larrance et al. 2007) as well as oil spills (Osofsky et al. 2010; Palinkas et al. 1993a). For example, the percentage of women reporting psychological victimization significantly increased from 34% prior to Hurricane Katrina to 45% following the storm, and hurricane-related stressors were a significant predictor

of this increase (Schumacher et al. 2010). Psychological aggression is known to be a precursor to physical aggression in marriage (Cascardi et al. 1995; Murphy and O'Leary 1989), which in turn is linked to a variety of mental health disorders, including depression, PTSD, and suicidal ideation (Anastario et al. 2009; Coker et al. 2002; Forbes et al. 2014; Schumacher et al. 2010). Women are especially vulnerable to domestic violence, making the study of domestic conflict in the context of the DHOS and its related stressors particularly relevant.

These results all point to substantial adverse mental health effects across various populations exposed to several different oil spills. Women in particular represent a vulnerable yet influential population. They are often central to decision-making processes within families, particularly with respect to decisions regarding health, support, diet, and child-rearing, and have remained relatively understudied with respect to the DHOS. (Men are the focus of the NIEHS-funded The GuLF Study.) The objective of this study is to describe the relationship between DHOS exposure and mental health among women living in the southern coastal Louisiana parishes that were affected by the Deepwater Horizon Oil Spill.

Methods

Study Design and Population

The Women and Their Children's Health (WaTCH) Study is a longitudinal study of women in seven southern coastal parishes of Louisiana (Jefferson, Lafourche, Orleans, Plaquemines, St. Bernard, St. Mary, and Terrebonne) to assess the health effects of the DHOS. Data for the current analysis are from the first wave of interviews conducted between July 2012 and August 2014. Women were recruited randomly through an address-based sampling frame, with under-sampling from the larger, more urban parishes (Orleans and Jefferson). Volunteers were also

accepted, though they comprise less than 5% of the sample. Women were eligible to participate if they were between the ages of 18 and 80, lived in the study area at the time of the oil spill, were the female head of household, had not participated in either the Louisiana Gulf Women's Health Study (LGWHS) or the NIEHS Gulf Long-term Follow-up Study (National Institute of Environmental Health Sciences 2012), and were mentally, physically, and linguistically able to complete the telephone interview. Potential participants were sent an introductory letter describing the study and inviting them to participate. Once enrolled, a 60-minute computer-assisted telephone interview was administered, consisting of questions in medical, social, emotional and behavioral domains. The response rate was 45% as defined by the American Association for Public Opinion Research (American Association for Public Opinion Research (AAPOR) 2011).

The WaTCH Study was reviewed and approved by the Louisiana State University Health Sciences Center IRB and was granted a Waiver of Documentation of Informed Consent for the telephone interview. Study data were collected and managed using REDCap electronic data capture tools hosted at the Epidemiology Data Center at the LSUHSC School of Public Health (Harris et al. 2009). REDCap (Research Electronic Data Capture) is a secure, web-based application designed to support data capture for research studies, providing: 1) an intuitive interface for validated data entry; 2) audit trails for tracking data manipulation and export procedures; 3) automated export procedures for seamless data downloads to common statistical packages; and 4) procedures for importing data from external sources.

Measures

Exposure to the oil spill was measured using 9 self-reported items (Table 1). Five items (#4, #6-#9) were adapted from prior work done on the Exxon Valdez Oil Spill (Palinkas et al. 1992) and

subsequently used in other oil spill studies. The other four items were created for this study. Because these nine items were highly correlated with each other, we used the data-driven approach of exploratory factor analysis to identify the factors (latent variables) that fit the variance-covariance matrix of the observed variables. In order for each indicator to be on the same scale, we dichotomized all nine questionnaire responses. Item #1 was based on the question “Did you or anyone in your household lose any income due to disruption of employment or closing a business because of the oil spill?” and categorized based on yes/no responses. Item #2 was based on the question “Compared to other residents in your community, were you 1) hit harder by the oil spill than others, 2) affected about the same as others, or 3) affected less than others?” Responses were grouped into “hit harder” versus “affected less or about the same.” Item #3 was based on the question “How would you rate the influence of the oil spill on your household’s current financial situation?” Responses were grouped into categories as “very or somewhat negative influence” versus “very or somewhat positive or no influence.” Items #4 and #6-#9 were categorized based on yes/no responses. Item #5 on smell was created by combining questions on strength and frequency of smelling the oil and then dichotomizing it based on “any smell” versus “no smell.” A two-factor solution had the best fit, explaining approximately 57% of the variance. The first factor, consisting of items related to income loss, how hard participants were hit compared to others, and the oil spill’s influence on household finances, was labeled as Economic Exposure. The second factor, consisting of the other six items, was labeled as Physical Exposure.

Outcomes. Three mental health outcomes were assessed: depression, mental distress, and domestic conflict. Depression was measured using the 20-item Center for Epidemiological Studies Depression (CESD) Scale (Radloff 1977), with an established cutoff score of 16

suggestive of depressive symptoms (Eaton and Kessler 1981; Frerichs et al. 1981; Radloff 1977). Mental distress was measured using the Kessler-6 (K6) instrument (Kessler et al. 2002; Kessler et al. 2003) with scores of 13 or higher indicating probable serious mental distress (Aldworth et al. 2005; Kessler et al. 2003), and scores between 8 and 12 indicative of moderate mental distress (Galea et al. 2007; Kessler et al. 2003). Respondents were also asked if there had been an increase in the number of verbal or physical fights with their partner and an increase in the intensity of fights since the oil spill.

Covariates. Age was assessed in years as a continuous variable. Household income was reported for the year immediately preceding the oil spill and grouped into four categories: < \$20,000/year, between \$20,000 and \$50,000/year, between \$50,000 and \$80,000/year, and > \$80,000/year. Race was grouped into three categories: Non-Hispanic White, Non-Hispanic African American, and Hispanic/multi-racial/other (which also included Asian/Pacific Islanders and Native Americans). Education was measured as less than high school, high school graduate, and college or higher. Because the interviews occurred 2-4 years after the spill, we calculated the time between April 20, 2010, and the date of the interview and examined the effects of exposure while adjusting for this interval. It had no appreciable effect on depression or mental distress, therefore it was excluded from those models and used only for the domestic conflict outcomes.

Statistical Analysis

Statistical analyses were performed using SAS 9.4 (SAS Institute, Inc.), except for the exploratory and confirmatory factor analyses, which were conducted using MPlus, Version 7. Descriptive statistics were calculated for mental health outcomes, exposure items, and potential covariates. Poisson regression models with robust variances were used to calculate relative risks (RR) and 95% confidence intervals (CI) of the association between oil spill exposure and

depression and domestic conflict. For mental distress, we used separate Poisson regression models with robust sandwich estimators of the variance to calculate RR and 95% CI to predict moderate and severe mental distress (versus none) and severe mental distress (versus moderate and none). All models were adjusted for age, race, income and education. Time since spill was also adjusted for in the domestic conflict models. It was not related to either depression or mental distress.

Results

Study Population

Table 1 describes the demographic characteristics of the participants. Mean age was 45.7 years (SD 12.04). The majority of women had graduated high school but not college (59%), were non-Hispanic White (55%), and were married or living with a partner (63%). Pre-oil spill income among the participants was relatively evenly distributed between the four income groups, and 59% of the women were currently employed. The distribution of participants by parish generally mirrors what can be found in the 2010 census for women of similar age in the study area; e.g., Plaquemines and St. Bernard parishes yielded proportionally fewer respondents, reflecting their smaller population sizes. Participants were interviewed on average 3.1 years (SD 0.38) after the oil spill.

Exposure

Exposure to the DHOS was grouped into economic or physical exposure (Table 1). The major items contributing to economic exposure consisted of reports that the oil spill had a somewhat or very negative influence on household finances (38%) and reports of lost household income due to a disruption of employment or the closing of a business because of the oil spill (26%). The

major items contributing to physical exposure consisted of reports that the spill had directly affected recreational activities (34%), smelling the oil (27%), and coming into physical contact with the oil in other ways (22%).

Mental Health Outcomes

Table 2 describes the mental health outcomes of the study sample. The average CESD depression score was 11.8 (SD 12.46). When grouped using the standard cut-off of 16, over 28% of the women in the sample had depressive symptoms. The mean K6 score on mental distress was 6.1 (SD 5.30). Over 13% of the sample scored in the severe mental distress range, while another 19% scored in the moderate mental distress category. With respect to domestic conflict, 16% of participants with a partner reported that the number of fights they had with their partner had increased since the oil spill, while 11% reported that the intensity of fights had increased.

Predictors of Depression

The model showing the relationship between depression and exposure to the oil spill, while adjusting for relevant covariates, is shown in Table 3. Women reporting greater economic exposure to the oil spill were 1.2 (95% CI 1.02-1.41) times as likely to exhibit depressive symptoms as women who were not economically exposed, and women reporting greater physical exposure were 1.2 (95% CI 1.01-1.43) times as likely to exhibit depressive symptoms as women who were not physically exposed. Greater pre-oil spill household income and higher education were protective for depressive symptoms. Hispanic, other race or multi-racial women were 1.3 (95% CI 1.1-1.5) times as likely to exhibit depressive symptoms as White women.

Predictors of Mental Distress

The relationship between mental distress (severe vs. moderate/none and severe/moderate vs. none) and exposure to the oil spill, while adjusting for relevant covariates, is shown in Table 4. Results indicate that while the effect of physical exposure to the oil spill was significant, the effect of economic exposure was not. Women reporting more physical exposure to the oil spill were 1.4 (95% CI 1.1-1.8) times as likely to exhibit signs of severe mental distress (vs. moderate/none) and 1.2 (95% CI 1.1-1.4) times as likely to exhibit signs of severe or moderate mental distress (vs. none) as women reporting less physical exposure. Greater income and education were protective against mental distress, while race/ethnicity and age were not associated.

Predictors of Domestic Conflict

The models showing the relationship between domestic conflict (increase in number and intensity of fights) and exposure to the oil spill, while adjusting for relevant covariates, are shown in Table 5. Both economic and physical exposure to the oil spill were associated with increased domestic conflict. Women reporting economic exposure to the spill were 1.7 (95% CI 1.3-2.1) times as likely to report an increase in the number of fights with their partner since the spill as women who were not economically exposed, and 1.6 (95% CI 1.2-2.2) times as likely to report an increase in the intensity of fights. Women reporting physical exposure to the oil spill were 1.7 (95% CI 1.3-2.2) times as likely to report an increase in the number of domestic fights and 1.6 (95% CI 1.2-2.2) times as likely to report an increase in the intensity of domestic fights as women who were not physically exposed. Higher income was protective against both types of domestic conflict, while more education was protective only against an increase in intensity.

Women self-reporting as Hispanic, multi-racial or other race were more likely to report an increase in the intensity of domestic fights as non-Hispanic White women.

Discussion

This study, conducted 2-4 years after the Deepwater Horizon Oil Spill, demonstrated high prevalence of poor mental health outcomes among women in southern coastal Louisiana. Prevalence of depressive symptoms as measured by the CESD was 28%, while prevalence of severe mental distress as measured by the K6 was 13%. Domestic conflict, measured by an increase in the number of fights with a partner since the oil spill, was reported by 16% of respondents, while an increase in the intensity of partner fights was reported by almost 11% of respondents.

Depression

Higher rates of depression after disasters is well-documented (Arata et al. 2000; Buttko et al. 2012; Carrasco et al. 2007; Cerdá et al. 2013; Galea et al. 2002; Lyons et al. 1999; McLeish and Del Ben 2008), and this study confirms this finding. Using the same metric, though not directly comparable, only about 20% of individuals in the general population would be expected to exhibit depressive symptoms (Radloff 1977). Estimates from the 1970s ranged from 21% of women in a nationally representative sample (Eaton and Kessler 1981) to 23.5% of women in a multi-ethnic probability sample in Los Angeles County (Frerichs et al. 1981); a 1997 study on premenopausal women in Boston demonstrated a prevalence of 22.4% (Harlow et al. 1999).

Within a disaster context, many other studies have shown unusually high rates of depression/depressive symptoms compared to population norms (Arata et al. 2000; Buttko et al. 2012; Carrasco et al. 2007; Cerdá et al. 2013; Galea et al. 2002; Lyons et al. 1999; McLeish and

Del Ben 2008). It is difficult to draw exact comparisons to the present study because of differences in sample selection, measurement instrument, and the nature of the trauma itself. However, the LGWHS, conducted in the same parishes as the present study during approximately the same time period, found a prevalence of depressive symptoms of 31%; that study differed from the current one in that it enrolled women who were wives or partners of clean-up workers, a potentially more highly exposed sample (Rung et al. 2015).

Though difficult to compare rates across studies, depression has been consistently associated with exposure to oil spills (Arata et al. 2000; Carrasco et al. 2007; Lyons et al. 1999; Palinkas et al. 1992; Palinkas et al. 1993b; Sabucedo et al. 2010) and a variety of other disasters (Norris et al. 2002), including typhoons (Amstadter et al. 2009), hurricanes (Davis et al. 2010; McLeish and Del Ben 2008), earthquakes (Cerdá et al. 2013), and terrorist attacks (Galea et al. 2002), using a variety of ways to quantify exposure. Our study adds to this body of work in finding that high depressive symptoms, after adjustment for characteristics commonly related to depression, are associated with greater physical and economic exposure to the DHOS. Other studies corroborate this finding. The LGWHS found a similar pattern of association between depression and physical exposure to the oil spill (Rung et al. 2015). Grattan (2011) found that depression was associated with income loss due to the DHOS. Similarly, Fan (2014) showed a relationship between current depression and DHOS-related job and income loss, as well as a relationship between depression and direct contact with oil.

It is striking that depression was found to be so high in this population. It is possible that respondents already exhibited higher rates of depression prior to the DHOS than their counterparts, due to exposure to previous disasters such as Hurricanes Katrina and Rita. Indeed, national survey estimates from 2008 show that depression, measured by a different metric (the

PHQ-8) than the one used in the current study, was slightly higher in Louisiana compared to the national average (9.3% vs. 8.9%) (Centers for Disease Control and Prevention 2011).

Immediately following the oil spill in 2010-2011, Louisiana's coastal parishes exhibited an even higher rate, at 16.4% on the PHQ-8 (Substance Abuse and Mental Health Services Administration 2013). Lack of pre-oil spill data precludes comparisons that could directly link depression to the oil spill in our sample. Nevertheless, our results are consistent with other evidence showing that populations residing closer to the epicenter of the DHOS and reporting more exposure are exhibiting higher than normal rates of depressive symptoms.

Mental Distress

The present study found that prevalence of severe mental distress (13%) as measured by the K6 is also higher than expected. Nationally in 2009, about 4% scored in the severe range, and in 2007 the prevalence in Louisiana was 5.3% (Centers for Disease Control and Prevention 2011). Rates of severe mental distress among adults in 32 counties in the Gulf Coast Disaster Area pre- and post-DHOS were 6% and 5%, respectively, showing little change (Substance Abuse and Mental Health Services Administration 2013). The LGWHS, on the other hand, found a prevalence of severe mental distress of 12% (Rung et al. 2015), while a late 2010 survey of 4 coastal Louisiana parishes found a prevalence of 15% (Osofsky et al. 2011), both quite similar to the present study. Rates begin to approach those found in the WaTCH Study as one moves closer in location and time to the DHOS.

Physical exposure to the oil spill is a predictor of mental distress in the WaTCH Study. This is contrary to findings of no association between any kind of exposure and mental distress among partners of oil spill workers in the LGWHS, though this lack of association may be due to the

smaller sample size in the LGWHS (Rung et al. 2015). The GSPS found no significant differences in severe mental distress from pre- to post-spill in 25 coastal counties of four affected states (Substance Abuse and Mental Health Services Administration 2013). These 25 counties, however, comprise all the counties bordering the Gulf Coast from Louisiana to the Florida panhandle, including the seven in the present study. Without an estimate of exposure, though, it is possible that the sample included many residents who were unexposed, thereby diluting any potential effect. Osofsky (2011), in contrast, found positive associations between the DHOS disrupting participants' lives and severe mental distress. Again, lack of pre-oil spill data prevents us from attributing the rates found in the present study solely to the oil spill, but data from Hurricane Katrina documented increases in mental distress using the same instrument in the same areas before and after the storm (Kessler et al. 2006). Indeed, even higher rates of severe mental distress than found in the current study were identified following Hurricane Katrina (Galea et al. 2007; Sastry and VanLandingham 2009), suggesting that the lingering effects of previous disasters may also contribute to making this population particularly vulnerable to a new disaster such as the DHOS.

Domestic Conflict

The items for domestic conflict used in the current study are not comprehensive descriptors of partner violence. Nevertheless, the finding that 16% of respondents reported an increase in the number of fights with their partner, and 11% reported an increase in their intensity, reflects an indication of marital/partner discord, which could escalate to more serious problems.

Relationship conflict is known to be associated with male-to-female physical abuse (Schumacher et al. 2001) and intimate partner violence (IPV), which in turn is associated with a myriad of adverse mental health consequences (Coker et al. 2002), such as depressive symptoms (Cascardi

et al. 1992; Cascardi and O'Leary 1992), depression (Cascardi et al. 1995; Gleason 1993), PTSD (Cascardi et al. 1995; Forbes et al. 2014; Gleason 1993; Kemp et al. 1991), generalized anxiety disorder (Gleason 1993) as well as numerous somatic symptoms (Follingstad et al. 1991).

Approximately 1.5 million women are raped and/or physically assaulted by an intimate partner annually in the United States (Tjaden and Thoennes 1998), making this a serious public health issue.

Significant life stressors, such as disasters, are known risk factors for partner aggression (Schumacher et al. 2001). Both economic and physical exposure to the DHOS are significantly associated with increased domestic conflict in the present study. This is consistent with data showing that disasters are related to intimate partner violence (Anastario et al. 2009; Harville et al. 2011; Larrance et al. 2007; Palinkas et al. 1993a; Palinkas 2012; Schumacher et al. 2010).

Studies after Hurricane Katrina of displaced persons living in FEMA trailers found a rate of IPV three times higher than US baseline rates (Larrance et al. 2007), a rate which increased another 5% a year later (Anastario et al. 2009). Women experiencing IPV were also at greater risk for major depression and suicidal ideation (Anastario et al. 2009). Similarly, Harville (2011) found that greater exposure to Hurricane Katrina was associated with increased likelihood of violent methods of conflict resolution among post-partum women in Louisiana. Even within the context of an oil spill disaster, similar patterns are found with respect to domestic violence. Residents who were highly exposed to the EVOS were significantly more likely to report conflict with their spouse or partner and to report increases in domestic violence in their community (Palinkas et al. 1993a; Palinkas 2012). After the DHOS, qualitative interviews and focus groups with community stakeholders showed evidence of increased fighting and domestic violence (Osofsky et al. 2010). Likewise, among partners of DHOS clean-up workers, prevalence of increased

partner fights was 33%, which was associated with both physical and economic exposure to the oil spill (Rung et al. 2015). More research related to domestic conflict and intimate partner violence after the DHOS needs to be conducted, as the conditions are present for further negative public health impact.

An alternative hypothesis for the present study's results is that the relationship between oil spill exposure and the mental health outcomes is non-linear. We explored this possibility by testing the effects of the squared exposure terms and by comparing model fit indices to models without the squared terms (data not shown). The quadratic models did not substantially improve the model fit, and the effect estimates did not substantially change with the squared terms. The exception was for severe or moderate mental distress, where physical exposure and the square of physical exposure were both significant, suggesting the possibility of a leveling out of the effect of exposure on distress at higher levels of distress. Because the sample size at the very high ends of the scales was limited, further exploration of this possibility is warranted in more appropriately powered studies.

Several limitations of this study should be noted. First, no data on prior history of mental health outcomes were available, making it difficult to ascertain whether some of these disorders were due to conditions that pre-dated the oil spill. Nevertheless, the relationships between reported levels of oil spill exposure and both depression and mental distress were in keeping with estimates seen in other disaster studies. A second important limitation is that these data are cross-sectional, and the results should be interpreted with appropriate caution. An alternative explanation of the study's results is that individuals with higher levels of mental health problems tend to report more exposure to the oil spill. Third, there is no standard method to measure exposure to an oil spill. In the absence of biomarkers or other objective measures, studies often

rely on survey data or geographic proximity to the oil spill as proxy measures of exposure. There are thus a wide variety of approaches used to characterize exposure across studies, making comparisons difficult. We chose a method that combines several questionnaire items into two composite variables, which essentially assesses the degree of impact of exposure on subjects' lives. Nevertheless, this study employed many of the same items used in other oil spill studies, and results appear to be robust regardless of method used. Fourth, this study included only women with a response rate of 45%, so comparisons to populations of both sexes and generalization to the wider population should be made with caution. Fifth, it is possible that mental health outcomes were under-reported due to stigmatization or lack of participation by those most heavily affected, which would make our current estimates conservative. On the other hand, selection bias whereby potential respondents were more inclined to participate because they had health-related complaints may have offset the under-reporting. Finally, the study accepted volunteers as well as randomly sampled participants, potentially introducing selection bias into the results. However, volunteers accounted for less than 5% of the sample. Excluding the volunteers (data not shown) produces no meaningful changes in the results.

Despite these limitations, the WaTCH Study is a large, population-based study of women in a particularly vulnerable area of the country that a) improves on estimates of survey-derived exposures to oil spills by capturing two distinct aspects of exposure, physical and economic exposure, and b) provides important information on the mental health correlates of the Deepwater Horizon Oil Spill that could lead to improved planning and disaster mitigation in the future.

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Table 1. Baseline Characteristics of WaTCH Study Sample, N=2852.

Characteristic	N (%)
Education	
Less than high school	327 (11.8)
High school graduate	1649 (59.3)
College or higher	804 (28.9)
Pre-Oil Spill Household Income	
Less than \$20,000/yr	645 (24.9)
\$20,000 - \$50,000/yr	763 (29.5)
\$50,000 - \$80,000/yr	545 (21.1)
Over \$80,000/yr	636 (24.6)
Race/Ethnicity	
Non-Hispanic White	1522 (54.6)
Non-Hispanic African American or Black	945 (33.9)
Hispanic/Multi-racial/other	319 (11.5)
Marital Status	
Married/living with partner	1785 (62.7)
Widowed/divorced/separated/never married	1063 (37.3)
Currently Employed	
Yes	1562 (59.1)
No	1081 (40.9)
Louisiana Parish of Residence at Time of Oil Spill	
Jefferson	489 (17.2)
Lafourche	540 (18.9)
Orleans	532 (18.7)
Plaquemines	184 (6.5)
St. Bernard	192 (6.7)
St. Mary	385 (13.5)
Terrebonne	530 (18.6)
Exposure to the Deepwater Horizon Oil Spill	
Economic Exposure	
1. Lost HH income due to employment disruption/closing of business because of oil spill	743 (26.2)
2. Hit harder by oil spill compared to others in community	167 (6.0)
3. Oil spill had somewhat or very negative influence on HH financial situation	1064 (37.8)
Physical Exposure	
4. Oil spill caused damage to areas fished commercially	195 (6.8)
5. Extent and frequency of smelling oil	
No smell exposure	1694 (62.5)
Any smell exposure	1016 (37.5)
6. Came into physical contact with oil in other ways (e.g., during home, recreation, hunting, fishing or other activities)	624 (22.1)
7. Oil spill directly affected recreational hunting/fishing /other activities of	972 (34.3)

household	
8. Worked on any oil spill clean-up activities	55 (1.9)
9. Any property lost or damaged due to oil spill or clean-up	72 (2.5)
Age, years (mean ± SD)	45.7 ± 12.04
Time since DHOS, years (mean ± SD)	3.1 ± 0.38
Missing data: Education (n=72); income (n=263); race (n=155); marital status (n=4); current employment (n=209); lost income (n= 15); hit harder (n=56); negative influence (n=40); smell (n=142); physical contact (n=28); lost/damaged property (n=4).	

Table 2. Mental Health Characteristics of WaTCH Study Population, N=2852.

Characteristic	n (%)
Depression (CESD) Score (mean ± SD)	11.8 ± 12.46
Depression Groups	
Presence of depressive symptoms (≥16)	766 (28.1)
No depressive symptoms (<16)	1964 (71.9)
Serious Mental Distress (K6) Score (mean ± SD)	6.1 ± 5.30
Mental Distress Groups	
Severe mental distress (≥13)	368 (13.2)
Moderate mental distress (5-13)	538 (19.4)
No mental distress (<5)	1874 (67.4)
Domestic Conflict	
Number of fights with partner has increased since oil spill (a)	369 (15.8)
Intensity of fights with partner has increased since oil spill (b)	265 (11.4)
Missing data: Depression (n=122); mental distress (n=72); number of fights with partner (n=72), intensity of fights with partner (n=76). (a) among those who reported having a partner, N=2330 (b) among those who reported having a partner, N=2326	

Table 3. Adjusted Associations with Depression, N=2533.

	Depressive Symptoms (CESD \geq16)
	RR (95% CI)
Exposure to oil spill	
Economic Exposure	1.2 (1.02, 1.41)
Physical Exposure	1.2 (1.01, 1.43)
Pre-Oil Spill Household Income (ref=LE \$20K/yr)	
\$20K-\$50K/yr	0.7 (0.6, 0.8)
\$50-\$80K/yr	0.5 (0.4, 0.7)
\$80K/yr+	0.4 (0.3, 0.5)
Race (ref=non-Hispanic White)	
Non-Hispanic Black	1.1 (1.0, 1.3)
Hispanic/multi-racial/other	1.3 (1.1, 1.5)
Education (ref=less than high school)	
High school graduate	0.7 (0.6, 0.8)
College or higher	0.6 (0.4, 0.7)
Age, years	0.99 (0.99, 1.00)

Table 4. Adjusted Associations with Mental Distress, N=2571.

	Mental Distress (K6) (a)			Mental Distress (K6)		
	Severe vs. Moderate/None			Severe/Moderate vs. None		
	RR	95% CI	95% CI	RR	95% CI	95% CI
Exposure to oil spill						
Economic Exposure	1.3	1.0	1.7	1.0	0.9	1.1
Physical Exposure	1.4	1.1	1.8	1.2	1.1	1.4
Pre-Oil Spill Household Income (ref=LE \$20K/yr)						
\$20K-\$50K/yr	0.6	0.4	0.7	0.8	0.7	0.8
\$50-\$80K/yr	0.4	0.3	0.5	0.7	0.6	0.8
\$80K/yr+	0.3	0.2	0.5	0.6	0.5	0.7
Race (ref=non-Hispanic White)						
Non-Hispanic Black	0.8	0.6	1.0	1.0	0.9	1.1
Hispanic/Multi-racial/other	1.0	0.7	1.3	1.1	1.0	1.3
Education (ref=less than high school)						
High school graduate	0.6	0.4	0.7	0.8	0.8	0.9
College or higher	0.3	0.2	0.4	0.8	0.7	0.9
Age, years	1.0	1.0	1.0	1.0	1.0	1.0
(a) Serious mental distress defined by K6 scores ≥ 13 ; moderate mental distress defined by K6 scores between 8 and 12; no mental distress defined by K6 scores < 8 .						

Table 5. Adjusted Associations with Increased Number and Increased Intensity of Partner Fights.

	Increase in Number of Fights (N=2168)	Increase in Intensity of Fights (N=2166)
	RR (95% CI)	RR (95% CI)
Exposure to oil spill		
Economic Exposure	1.7 (1.3, 2.1)	1.6 (1.2, 2.2)
Physical Exposure	1.7 (1.3, 2.2)	1.6 (1.2, 2.2)
Time since spill, years	1.2 (0.9, 1.5)	1.4 (1.1, 1.9)
Age, years	1.0 (1.0, 1.0)	1.0 (1.0, 1.0)
Income (ref= LE \$20K/yr)		
\$20K-\$50K/yr	0.8 (0.6, 1.0)	0.8 (0.6, 1.0)
\$50-\$80K/yr	0.6 (0.5, 0.9)	0.6 (0.4, 0.9)
\$80K/yr+	0.7 (0.5, 0.9)	0.6 (0.4, 0.9)
Race (ref=non-Hispanic White)		
Non-Hispanic Black	1.0 (0.8, 1.3)	1.1 (0.8, 1.5)
Hispanic/Multi-racial/other	1.3 (1.0, 1.7)	1.6 (1.2, 2.2)
Education (ref=less than high school)		
High school graduate	0.9 (0.7, 1.2)	0.9 (0.6, 1.2)
College or higher	0.9 (0.6, 1.2)	0.6 (0.4, 0.9)