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Individual-level Exposure to Disaster, Neighborhood Environmental Characteristics, and their Independent and Combined Associations with Depressive Symptoms in Women

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Abstract

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Purpose—The severity of the stress response to experiencing disaster depends on individual exposure and background stress prior to the event. To date, there is limited research on the interaction between neighborhood environmental stress and experiencing an oil spill, and their effects on depression. The objective of the current study was to assess if the association between exposure to the Deepwater Horizon Oil Spill (DHOS) and depressive symptoms varied by neighborhood characteristics.

Methods—U.S. Census data (2010) and longitudinal data collected in two waves (2012–2014 and 2014–2016) from female residents (N = 889 (Wave I), 737 (Wave II)) of an area highly affected by the DHOS were analyzed. Multilevel and individual-level negative binomial regressions were performed to estimate associations with depressive symptoms in both waves. An interaction term was included to estimate effect modification of the association between DHOS exposure and depressive symptoms by neighborhood characteristics. Generalized estimating equations were applied to the negative binomial regression testing longitudinal associations.

Results—Census tract-level neighborhood characteristics were not associated with depressive symptoms. Exposure to the DHOS and neighborhood physical disorder were associated with depressive symptoms cross-sectionally. There was no evidence of effect modification; however, physical/environmental exposure to the DHOS was associated with increased depressive symptoms only among women living in areas with physical disorder. Exposure to the DHOS remained associated with depressive symptoms over time.

Conclusions—Findings support the enduring consequences of disaster exposure on depressive symptoms in women and identify potential targets for post-disaster intervention based on residential characteristics.

Keywords

depression; social epidemiology; neighborhood/place; multilevel modeling; disaster

Disasters have increased in number and magnitude over time [1]. Disasters are traumatic events that affect large populations, and can lead to stress and ultimately poor mental health. An individual's stress responses to disasters is a function of the interplay of multiple factors, including intensity and suddenness of the event and individual characteristics, such as his/her level of background stress prior to the event [2]. After disasters, some people often experience mild or moderate depressive symptoms while other higher risk individuals will have severe reactions and experience clinical depression [2]. Depression, even in the absence of experiencing disaster, is one of the most common psychiatric disorders affecting adults in the United States [3,4], and examining depression in the post-disaster context is imperative.

Within the context of disaster, people often experience several stressful life events concurrently, including physical and mental trauma and loss. Such life events, particularly within the context of chronic background stressors such as low socioeconomic status, exert strong influences on depression [5]. Thus people experiencing chronic stress prior to a disaster may be particularly vulnerable to adverse mental health afterwards. Within an individual's environment, neighborhood factors such as economic disadvantage [6,7] and physical disorder [8,9] have been linked to increased depressive symptoms and decreased

psychological well-being. In order to guide disaster preparedness and response, it is important to identify whether post-disaster depression varies by neighborhood conditions.

Sex differences in the association between community factors and mental health have been demonstrated. Burke et al. found noticeable sex differences in which women were more likely than men to perceive that negative community factors (e.g., graffiti, noise) affected mental well-being [10]. Women also experience depression at twice the rate of men [11–14]. A previous study of African American women stated that the combination of neighborhood factors and recent stressful life events has a strong impact on depression [15]. Furthermore, prior literature has demonstrated that maternal depression is associated with increased risk of mental, emotional, and behavior health problems across the lifespan of their offspring [16–21]. Due to prior evidence of associations with and possible variation in depressive symptoms by neighborhood context and the substantial impact women's mental health can have on their children, understanding post-disaster mental health in women offers mental health and well-being implications for communities affected by disaster. In this study, we chose to focus on post-disaster depressive symptoms only among women.

One type of disaster that has lasting influences on a community is an oil spill [22]. Previous research demonstrates that oil spill exposures are associated with a range of poor mental health outcomes, including increased levels of depression [23–28]. However, to date, studies of post-oil spill depression have not examined mental health consequences of the interaction between the neighborhood environment and experiencing an oil spill. Of the four oil spill studies that found an association between oil spill exposure and depressive symptoms, three did not examine the simultaneous impacts of neighborhood environment and oil spill exposure on depressive symptoms [26,23,29]. The one study that included community level factors at the county level reported no association between these factors and depressive symptoms [25]. However, results may be due to the modifiable areal unit problem, in which aggregating smaller data points into a larger area can remove associations that are actually present in the lower level [30]. Therefore, further research is necessary to examine how neighborhood factors measured on the census-tract and individual-level may modify the effect of oil spill exposure on depressive symptoms. The objective of the current study is to longitudinally assess if the association between exposure to the Deepwater Horizon Oil Spill (DHOS), the largest marine spill in U.S. history, and depressive symptoms varies by neighborhood characteristics. We hypothesize that the association between DHOS exposure and increased depressive symptoms will be stronger among women residing in neighborhoods with greater economic disadvantage and physical disorder than among women residing in neighborhoods with lower levels of each.

METHODS

Study design and population

Participants of this study were a subset of the Women and Their Children's Health (WaTCH) Cohort Study (N = 2,852). WaTCH was designed to assess the consequences of the DHOS on the physical and mental health of women and children. Eligibility criteria for women of the WaTCH Study included being a female between 18 and 80 years old and residence in southeastern Louisiana at the time of the DHOS (April 20, 2010). Sampling methods and

participant recruitment were described in previous publications [27,31]. The WaTCH Study response rate of 45% [31] was acceptable based on the American Association of Public Opinion's standard [32]. Though there was no data available on the characteristics of non-respondents, we compared the WaTCH population to the source population of southern Louisiana residents using 2010 U.S. Census and American Community Survey estimates data (Table S1). There were some notable differences in demographic characteristics between the study and underlying population in race/ethnicity, age, education, and marital status. WaTCH women were less likely to be Hispanic and of any other race than black or white, were younger, were more educated, and were more likely to be currently married than the population of southeastern Louisiana women.

In the first wave of data collection (2012–2014), participants completed telephone interviews approximately 60 minutes in length and subsequently were invited to participate in home visits consisting of other forms of data collection, including neighborhood audits by trained certified medical assistants (CMAs). The neighborhood audit tool, previously validated [33,34] and adapted from prior studies [35], involved the examination and recording of physical conditions in the block surrounding the participant's home (e.g., litter in the streets, abandoned buildings and cars, etc.). Later, a second wave of telephone interviews was completed (2014–2016). Verbal assent and signed informed consent were obtained prior to telephone interviews and home visits, respectively. The study protocol was approved by the Louisiana State University Health Sciences Center Institutional Review Board.

For this analysis, inclusion criteria included completion of the home visit and residence in the same census tract during the DHOS and the first interview date. Of the 2,852 WaTCH participants, 1,100 were eligible for the current study (Figure S1).

Measures

Depressive symptoms—During both telephone interviews, depressive symptomatology was assessed using the Centers for Epidemiologic Studies Depression Scale (CES-D), a widely used 20-item self-report screening tool suitable for use in the general population due to its high psychometric properties [36,37]. The 20 items were summed, and CES-D scores could range from 0 to 60, with higher scores indicating higher levels of depressive symptoms.

Oil Spill Exposure—Nine dichotomous items, described elsewhere [27], were collected during the Wave I telephone interview and were used to estimate individual exposure to the DHOS. Five of the nine exposures (i.e., participation in DHOS cleanup, physical contact with oil, property loss or damage due to the DHOS, damage to areas fished commercially, and the DHOS affecting recreational activities) have been used in prior oil spill studies to estimate oil spill exposure [23,29,25]. Four items (i.e., smelling of oil, income loss due to the DHOS, greater loss in comparison to others in the community, and negative influence of the DHOS on household finances) were developed for this study to assess additional aspects of oil spill exposure. Similar questions to these have been used in prior oil spill studies [38,24].

Item response theory modeling of categorical data was used as a data reduction tool to assess how multiple items clustered into DHOS exposure categories. Identification of the best factor solution was described previously [27]. Two factors explained approximately 57% of the variance. Six items related to physical/environmental exposure loaded on factor one ($\alpha = 0.84$) and three items related to economic exposure loaded on factor two ($\alpha = 0.80$). Individual scores for each factor were calculated by summing the variables that clustered into each DHOS exposure factor. Physical/environmental DHOS exposure summed scores were collapsed into the following categories: (1) unexposed (score = 0); (2) low (score = 1); and (3) high (score > 1). Economic DHOS exposure summed scores were collapsed into two categories: (1) unexposed (score = 0) and (2) any exposure (score > 0).

Neighborhood Economic Disadvantage—Neighborhood economic disadvantage was measured at the census tract-level, similar to prior studies [39,7,9,40,6,15,41]. Following established procedures [39,42], confirmatory factor analysis was performed on census-tract level variables extracted from the 2010 United States Census and the 2010 American Community Survey. The one-factor solution for neighborhood economic disadvantage ($\alpha = 0.80$) was retained and included the following: percentage of Black residents; percentage of renter occupied housing units; percentage unemployed; percentage of families living below the poverty-level; and percentage of households receiving public assistance. Census-tract factor scores for neighborhood economic disadvantage were extracted for regression modeling purposes.

Neighborhood Physical Disorder—Physical disorder was estimated by the presence or absence of six indicators identified during the neighborhood audit. Item response theory modeling was performed on these variables. The best factor solution was identified through a combination of model fit statistics, a scree plot of the eigenvalues, factor loadings, and interpretability of factors [43–45]. Results supported a two-factor structure of physical disorder, namely “litter” (empty beer or liquor bottles, cigarette butts or packages, and garbage/litter on the street or sidewalks; $\alpha = 0.69$) and “signs of community decline” (abandoned cars/buildings and graffiti; $\alpha = 0.51$). Individual scores for litter and signs of community decline were summed and collapsed into three categories: none (score = 0), low (score = 1), and high (score > 1).

Covariates—Several self-reported covariates assessed during the telephone interviews were considered as potential confounders based upon our construction of directed acyclic graphs [46] and prior literature [47–50]. Demographic variables included race (Non-Hispanic White, Non-Hispanic Black, Other (Hispanic, Multiracial, and any other race)); age (18–49 years, 50 years and older); education (less than high school, high school graduate, college graduate or beyond); annual household income in the year prior to the DHOS and at Wave II (less than \$20,000; \$20,0001 – \$40,000; \$40,001 – \$60,000; \$60,001 or greater); marital status (married/living with partner, never married/widowed/divorced/separated); and current employment status (employed, unemployed/retired). Continuous potential confounders included perceived social support, a summary score of five items; the amount of time (months) between the DHOS and telephone interview dates; and number of children at Wave I.

Statistical analysis

All factor analyses were conducted using Mplus, Version 7 (Muthén & Muthén, Los Angeles, California) for Windows. Subsequent analyses were conducted in SAS, Version 9.4 (SAS Institute, Inc., Cary, North Carolina) of the SAS System for Windows. Sample characteristics were examined by calculating frequencies for categorical variables. Means or medians, standard deviations or interquartile ranges, and ranges were calculated for continuous variables. CES-D scores were examined for each category of DHOS exposure and physical disorder, and Kruskal-Wallis tests were performed to estimate crude CES-D score differences between exposure categories. Due to overdispersion and right-skewness of CES-D scores, negative binomial regressions were applied to test adjusted associations.

Multilevel models were analyzed by *PROC GLIMMIX* in SAS, using the Newton-Raphson optimization technique. In order to estimate the intraclass coefficient (ICC) and assess the amount of variation in depressive symptoms present at the census tract-level, regression analyses began with the null random intercept model. Next, individual-level exposures, census tract-level neighborhood economic disadvantage, and confounders were included in the adjusted multilevel model predicting CES-D score at Wave I. Covariates included in all models were either determined a priori or those that changed estimates of the main exposures by more than 10% (race, education, income, perceived social support, and time between the DHOS and interview).

To estimate individual-level, cross-sectional associations with robust standard errors, *PROC GENMOD* was applied in SAS. Next, multiplicative interaction between DHOS exposure and neighborhood physical disorder was tested by including an interaction term. Additive interaction was assessed through estimation of the relative excess risk due to interaction (RERI) [51,52].

To assess if associations remained over time, the generalized estimating equations (GEE) method [53] was used to account for correlations between time-varying covariates (e.g., CES-D score at Waves I and II) in an adjusted individual-level model. For all models, incidence rate ratios and 95% confidence intervals were estimated.

RESULTS

Population characteristics and bivariate associations

Of 1,100 eligible women, 211 were excluded from the cross-sectional analysis due to missing values for variables included in final models, resulting in an analytic sample size of 889 (Figure S1). Similar to the WaTCH study population in its entirety, there were notable differences in demographic characteristics between the analytic sample and the population of southeastern Louisiana women (Table S1). Ineligible and excluded WaTCH women were similar to included WaTCH women in regards to age, education, marital status, and current employment (Table S2). However, ineligible and excluded women were more likely to be non-Hispanic white and have higher incomes. Of the 889 women included in the cross-sectional analysis, 152 were excluded from longitudinal analysis due to missing values, resulting in an analytic sample size of 737 (Figure S1). Women excluded from longitudinal

analysis were more likely to be non-Hispanic White and have lower levels of litter surrounding their homes than women included in the longitudinal analysis.

Of the 889 women included in the analysis, slightly over half were non-Hispanic White (52.3%) and the majority were between the ages of 18–49 (68.2%), had attained at least a high school education (86.5%), and were currently married or living with a partner (61.2%) (Table 1). Almost half of women were economically exposed (47.7%) and almost a third reported high physical/environmental exposure to the DHOS (31.9%). Smaller percentages of women had high levels of community decline (11.7%) and litter (24.3%) surrounding their homes. Approximately 32% and 37% of women at Wave I and Wave II, respectively scored above the established cut-off value of 16 on the CES-D, which is indicative of probable clinical depression [36]. Women in the study resided in 174 census tracts. On average, there were approximately 5 women per census tract.

For all individual-level exposures, the median CES-D score increased as exposure increased at both Waves (Table 2). Women with high exposure to the DHOS and neighborhood physical disorder had the highest median CES-D scores on average. Women with no DHOS physical/environmental exposure had median CES-D scores of 7 and 9 at Waves I and II, respectively, while women with high physical/environmental exposure had median CES-D scores of 11 and 13 ($p < 0.001$, $p = 0.07$). The largest differences in CES-D scores were between women who lived in areas with no signs of community decline (median CES-D scores of 7 and 9), and women who lived in areas with high levels of community decline (median CES-D scores of 14 and 17) at Waves I and II, respectively ($p < 0.001$, $p = 0.006$).

Census tract-level variation in depressive symptoms

In the null random intercept model containing census tract membership as the sole predictor of CES-D score, approximately 9% of the variance in depressive symptoms at Wave I was explained by census tract membership ($ICC = 0.09$). The ICC reduced to 0.03 after the addition of census tract-level neighborhood economic disadvantage, individual exposures of interest, and adjustment for confounding to the null model (Table 3, Model 1), suggesting that these variables explained a portion (65%) of the census tract-level variation in mean CES-D score at Wave I. Despite this, the overall explainable variation in CES-D scores by census tract membership was small, and neighborhood economic disadvantage was not associated with depressive symptoms after adjustment for race, education, income, social support, and time elapsed between the DHOS and Wave I interview (adjusted IRR (aIRR): 1.01; 95% confidence interval (CI): 0.98, 1.04).

Individual-level variation in depressive symptoms

Reducing the multilevel model to an individual-level model revealed quantitatively similar estimates (Table 3, Model 2). Adjusted associations between depressive symptoms and high physical/environmental DHOS exposure and high levels of community decline remained. Among women with high physical/environmental exposure, the mean CES-D score at Wave I was 29% higher than mean scores of women with no physical/environmental exposure after adjustment (95% CI: 1.11, 1.51). The average CES-D score for women with high levels

of community decline was 29% higher than the average score for women with no signs of community decline surrounding their homes after adjustment (95% CI: 1.06, 1.58).

Results of the GEE individual-level model predicting CES-D score at Wave II showed similar associations between physical exposure to the DHOS and depressive symptoms as Wave I and an association with economic exposure became evident (Table 3, Model 3). Economic exposure to the DHOS was associated with increased depressive symptoms at Wave II after adjustment (aIRR: 1.21; 95% CI: 1.08, 1.37). High physical/environmental exposure to the DHOS, though slightly attenuated, remained associated with increased risk of depressive symptoms (aIRR: 1.19; 95% CI: 1.03, 1.38); however, high levels of community decline were no longer associated with depressive symptoms (aIRR: 1.07; 95% CI: 0.91, 1.28) at Wave II.

DHOS exposure and neighborhood physical disorder were both independently associated with CES-D only in Wave I, so interaction terms were estimated (Table 4). Though median CES-D score increased as physical/environmental exposure to the DHOS and signs of community decline increased, associations in each of the joint categories were not supported after adjustment. However, when stratifying by levels of community decline, high physical/environmental exposure to the DHOS was associated with higher depressive symptoms only among women living in areas with signs of community decline (low community decline, aIRR: 1.72; 95% CI: 1.23, 2.41 and high community decline, aIRR: 1.56; 95% CI: 1.05, 2.32). Though the associations between depressive symptoms and physical/environmental exposure were only among women living in areas with community decline, the associations did not exhibit enough heterogeneity to support multiplicative or additive interaction.

DISCUSSION

The objective of this study was to assess whether the association between exposure to the DHOS and depressive symptoms varies by characteristics of the neighborhood environment. Census tract-level neighborhood characteristics were not associated with depressive symptoms. Exposure to the DHOS and neighborhood physical disorder were independently predictive of depressive symptoms. Specifically, high physical/environmental DHOS exposure and residing in areas with community decline were associated with short-term increased depressive symptoms. However, there was no evidence of effect modification. Later in time, both physical/environmental and economic exposure to the DHOS were associated with increased depressive symptoms, while community decline was not.

With further examination of the cross-sectional data, we found the association between depressive symptoms and high physical/environmental DHOS exposure was present only among women living in areas with signs of community decline. It was also evident that women residing among low signs of community decline have higher risk of depressive symptoms associated with DHOS exposure than women residing among high signs of community decline. These results are counterintuitive and warrant further investigation.

Results from our investigation did not support census tract-level neighborhood characteristics as possible factors modifying the association between exposure to the DHOS

disaster and depressive symptoms. These findings may be attributable to limited statistical power to identify cross-level associations, inadequacy of the census tract units of measurement of neighborhood characteristics, or to the possibility that these exposures actually do not play an important role on depressive symptoms. However, the directly observed immediate neighborhood environment surrounding the participants' homes was associated with risk of experiencing depressive symptoms. Furthermore, though results did not support the modifying effect of community decline on the association between DHOS exposure and depressive symptoms, physical/environmental DHOS exposure was only associated with depressive symptoms among women within neighborhoods with signs of community decline. Community decline can be viewed as a sign of lack of neighborhood resources and other forms of community social capital. A lack of social capital in these women's neighborhoods may be a reason for the observed associations. The buffering model of social support states that stress resulting from loss (e.g., unemployment) or other life events increases depression, however social support acts as a buffer in this process [54]. Lack of social support to buffer the effect of experiencing other stressors, may lead to increases in experiencing depressive symptoms. If individual stress is coupled with the degradation of community resources and social support systems that may occur in post-disaster communities, deleterious mental health consequences can occur.

Physiologic pathways could also have been affected by neighborhood and DHOS-related stressors. In response to acute or chronic stress, the hypothalamic-pituitary-adrenal (HPA) axis is activated, and initiates the stress response of peripheral body systems. A review of prior literature and a meta-analysis support that levels of hormones (e.g., cortisol, dehydroepiandrosterone sulfate) affected by HPA axis activity are associated with depression [55,56]. It is possible that the acute and chronic stress experienced by the WaTCH women as a result of the DHOS could cause changes in HPA axis activity, possibly leading to depressive symptoms. This physiologic mechanism may be similar in other women concurrently experiencing chronic stress and the acute stress resulting from unexpected, negative life events. Results of this study may be similar if exploring the coupled effects of chronic and disaster-related acute stress in other populations of women.

The economic impact of the DHOS had a stronger influence on depressive symptoms in the later time period (Wave II) following the spill than in the proximate period post-spill. Prior studies of the Exxon Valdez Oil Spill and the DHOS suggest economic exposure associations with poor mental health outcomes in the immediate aftermath of the spills [57,24,23,58,26,29]. Our results suggest that these associations may strengthen over time. In the current study, associations with indirect economic exposures only appeared in the later years. These results could reflect the chronic stress from loss of income and its accumulation over time. Previous studies indicate that "slow-motion technological disasters" which have a lengthy duration and ambiguous endings, can create lingering uncertainties and perceived loss of control, thus leading to more long-term severe psychosocial and psychological impacts [59]. Thus, the economic impacts of the DHOS may result in psychological consequences observed much later after the disaster itself.

This study is limited by some of the common problems of neighborhood and health research. In contrast with the physical disorder variable, which is specified at the individual level,

census tract-level neighborhood economic disadvantage is a derived variable constructed by summarizing the characteristics of individuals in a group [60,61]. In this analysis, census tract-level neighborhood economic disadvantage is no longer associated with depressive symptoms after adjustment for individual-level socioeconomic characteristics, raising the question of whether the neighborhood variable was actually describing something above and beyond summed individual qualities. An additional widespread concern is potential selection bias, whereby individuals non-randomly, self-select into neighborhoods. Their selection of neighborhood residence may reflect underlying common causes, such as economic and social processes, that cause similar individuals to reside in similar neighborhoods [62] thus producing the appearance of clustering of health outcomes.

Additional limitations include a possibility of measurement bias due to the use of self-reports to collect exposure data. People experiencing depressive symptoms during Wave I may have been more likely to recall more negative exposures to the DHOS. Such bias could lead to overestimation of the associations between exposure to the DHOS and depressive symptoms. However, questions about physical/environmental exposure to the DHOS (e.g., participation in cleanup, physical contact with oil) are uncommon events unlikely to be over- or under-reported regardless of current depressive symptoms. There is potential residual confounding due to unmeasured influences that could predict depression, such as other neighborhood-level factors [7,40], and the possibility that depressive symptoms began prior to the DHOS. Nevertheless, the results were consistent with prior literature, supporting our findings.

Some caveats affect interpretation of the present results. Within the WaTCH Study population, affluent, non-Hispanic white women were more likely to be omitted from this analysis due to missing values or loss to follow-up which introduces the possibility of selection bias. However, women with higher incomes are often not residents of neighborhoods with signs of community decline and litter. Upon stratification by levels of community decline, data suggest associations between DHOS exposure and depressive symptoms were only present among women living in areas with signs of community decline. Therefore, we speculate that exclusion of these women may not strongly affect the current results. Upon further examination of the data (not shown) non-Hispanic white women and women with higher incomes were less likely to report depressive symptoms. These groups were also less likely to report DHOS exposure. Given the likelihood that less exposed, less depressed women likely living in areas with lower or no community decline were not in the analytic sample, we expect that if the results were affected by omission of these women, they would be a slight underestimation. More research beyond this study is necessary to assess this as a possibility. Furthermore, the analytic sample drawn from the WaTCH Study population is not perfectly representative of southeastern Louisiana women thus limiting target population inferences. Additionally, the study took place in coastal Louisiana, limiting its generalizability to other populations in the United States. However, the psychological and physiological processes involved in the stress response to multiple stressors is likely to be similar in other populations.

Despite these limitations, this study has several strengths. The WaTCH study is a robust data source consisting of a population-based sample of women that allows the exploration of

neighborhood characteristics on health. Also, prior oil spill and neighborhood studies utilizing the CES-D treat it as a normally distributed variable [63,29]. To account for overdispersion and right-skewness of the CES-D variable, we performed negative binomial regression which may better approximate the true distribution of CES-D scores in the population and improve inference. Other strengths include the assessment of depressive symptoms in a large sample of women, both cross-sectionally and longitudinally, that showed results consistent in direction and magnitude.

Conclusion

Economic and physical/environmental exposure to the DHOS, as well as signs of neighborhood decline were independent predictors of higher depressive symptoms in women at various points in time. High physical/environmental DHOS exposure was associated with increased depressive symptoms short-term post-disaster only among women residing in neighborhoods evidencing community decline. Though the DHOS is just one disaster, psychosocial stress experienced by women affected by the DHOS may be similar to psychosocial stress experienced by women affected by other disasters, and the psychological and physiologic mechanisms behind these associations could operate through the same pathways. Our results are thus important in the context of policies regarding disaster preparedness and response. Based on these results, future research focused on neighborhood context and the lingering effects of oils spills and other types of disaster is warranted.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Women and Their Children's Health (WaTCH) Study Home Visit Population Characteristics, Louisiana, 2012–2016 (N = 889)

	n	%
Race/Ethnicity		
Non-Hispanic White	465	52.3
Non-Hispanic Black	351	39.5
Other (Hispanic, Multiracial, Any other race)	73	8.2
Age (years)		
18–49	606	68.2
50 and over	283	31.8
Education		
Less than High School	120	13.5
High School Graduate	509	57.3
College or beyond	260	29.2
Annual Household Income (year prior to DHOS)		
\$20,000	254	28.6
\$20,001 – \$40,000	189	21.3
\$40,001 – \$60,000	157	17.7
\$ 60,001	289	32.5
Married/Living with Partner ^I	543	61.2
Currently Employed ^I	489	57.7
Economic DHOS Exposure		
None	465	52.3
Any	424	47.7
Physical/Environmental DHOS Spill Exposure		
None	342	38.5
Low	263	29.6
High	284	31.9
Signs of Community Decline ²		
None	630	70.9
Low	155	17.5
High	104	11.7
Litter		
None	439	49.4
Low	234	26.3
High	216	24.3
CES-D Score 16 at Wave I	282	31.7
CES-D Score 16 at Wave II ^I	270	36.6
	Mean (SD)	Range

	n	%
Number of Children	1 (0–2) ³	0 – 6
Perceived Social Support	4.1 (1.3)	0–5
Neighborhood Economic Disadvantage Factor Score ⁴	0.0 (3.1)	–5.0 – 11.1
Months between DHOS at Wave I	38.1 (4.1)	27.8 – 48.5
CES-D Score at Wave 1	9 (3–20) ³	0 – 53
Months between DHOS at Wave II	63.5 (5.4)	53.7 – 73.3
CES-D Score at Wave II ¹	11 (4–23) ³	0 – 57

Abbreviations: Deepwater Horizon Oil Spill (DHOS); Centers for Epidemiologic Studies Depression Scale (CES-D)

¹ 1 woman missing value for marital status; 41 women had missing values for employment status; 152 women had missing values for CES-D Score at Wave II.

² Signs of community decline include abandoned cars, abandoned buildings, and graffiti.

³ median (interquartile range)

⁴ Measured at the census-tract level (N = 173)

Table 2

Distributions of CES-D Scores at Waves I (N = 889) and II (N = 737) by DHOS Exposure and Neighborhood Physical Disorder Exposure Categories in the WaTCH Study Home Visit Population, Louisiana, 2012–2016

	Wave I			Wave II		
	Median	IQR	P*	Median	IQR	P*
DHOS Exposure						
Economic			< 0.001			< 0.001
None	7	2 – 16		9	4 – 18	
Any	10	4 – 24		14	5 – 28	
Physical/Environmental			< 0.001			0.07
None	7	3 – 16		9	4 – 19	
Low	8	3 – 19		11	4 – 23	
High	11	4 – 25		13	5 – 26	
Neighborhood Physical Disorder						
Signs of Community Decline			< 0.001			0.006
None	7	2 – 17		9	4 – 20	
Low	11	4 – 25		11	4 – 27	
High	14	7 – 31		17	5 – 28	
Litter			< 0.001			< 0.001
None	6	2 – 16		8	3 – 18	
Low	9	3 – 19		12	4 – 21	
High	13	5 – 28		15	7 – 33	

Abbreviations: Center for Epidemiologic Studies Depression Scale (CES-D); Deepwater Horizon Oil Spill (DHOS); Women and Their Children's Health Study (WaTCH); Interquartile Range (IQR)

* p-value estimated by Kruskal-Wallis non-parametric test

Table 3

Adjusted Incidence Rate Ratios and 95% Confidence Intervals of Higher Depressive Symptoms (CES-D Score) at Waves I and II in the WaTCH Study Home Visit Population, Louisiana, 2012–2016

	Wave I		Wave II
	Model 1: Multilevel Model	Model 2 ¹ : Individual-level Model	Model 3 ² : Individual-level Model
	aIRR (95% CI)	aIRR (95% CI)	aIRR (95% CI)
Neighborhood Economic Disadvantage	1.01 (0.98, 1.04)		
DHOS Exposure			
Economic			
Any	1.15 (1.00, 1.31)	1.14 (0.99, 1.30)	1.21 ^{**} (1.08, 1.37)
Physical/Environmental			
Low	1.05 (0.89, 1.23)	1.05 (0.89, 1.23)	1.07 (0.93, 1.23)
High	1.30 ^{**} (1.10, 1.53)	1.29 ^{**} (1.11, 1.51)	1.19 ^{**} (1.03, 1.38)
Physical Disorder			
Signs of Community Decline			
Low	1.18 (0.97, 1.43)	1.17 (0.98, 1.40)	1.05 (0.89, 1.24)
High	1.29 ^{**} (1.02, 1.63)	1.29 ^{**} (1.06, 1.58)	1.07 (0.91, 1.28)
Litter			
Low	1.04 (0.88, 1.24)	1.06 (0.90, 1.25)	1.06 (0.93, 1.22)
High	1.04 (0.85, 1.26)	1.04 (0.88, 1.23)	1.13 (0.97, 1.33)
ICC	0.03		

Abbreviations: Center for Epidemiologic Studies Depression Scale (CES-D); Women and Their Children's Health Study (WaTCH); Adjusted Incidence Rate Ratio (aIRR); Confidence Interval (CI); Deepwater Horizon Oil Spill (DHOS); Intraclass Coefficient (ICC)

¹N = 889

²N = 737

^{**}
p < 0.05

Note: The reference group for all tests for associations is none/unexposed. All models are adjusted for race/ethnicity, education, perceived social support, and months between the DHOS and interview. Model 1: Adjusted random intercept model (multilevel model) with neighborhood economic disadvantage random effects and individual-level exposures predicting CES-D score at Wave I; Model 2: Adjusted fixed effects model (individual-level model) predicting CES-D score at Wave I; Model 3: Generalized estimating equation (GEE) model predicting CESD score at Wave II, additionally controlling for whether participant moved between Waves I and II.

Table 4

Modification of the Effect of Physical/Environmental Exposure to the DHOS on Depressive Symptoms (CES-D) Score by Neighborhood Physical Disorder in the WaTCH In-Home Visit Population, Louisiana, 2012–2014 (N = 889)

CES-D Score						
No Physical/Environmental DHOS Exposure	Low Physical/Environmental DHOS Exposure	High Physical/Environmental DHOS Exposure	aIRR (95% CI); <i>P</i> for low and high physical/environmental DHOS exposure within strata of community decline			
Median CES-D Score	aIRR (95% CI) <i>P</i>	Median CES-D Score	aIRR (95% CI) <i>P</i>	Median CES-D Score	aIRR (95% CI) <i>P</i>	aIRR (95% CI) <i>P</i>
No Signs of Community Decline	6 1.00 reference	6	1.00 (0.82, 1.21)	9	1.21 (1.00, 1.46)	Low DHOS exposure: 1.01 (0.83, 1.22); 0.95 High DHOS exposure: 1.19 (0.98, 1.44); 0.08
Low Signs of Community Decline	9 0.98 (0.76, 1.27)	10	1.30 (0.87, 1.96)	19	1.38 (0.96, 1.99)	Low DHOS exposure: 1.32 (0.90, 1.95); 0.16 High DHOS exposure: 1.72 (1.23, 2.41); 0.002
High Signs of Community Decline	11 1.26 (0.89, 1.77)	14	1.02 (0.63, 1.64)	23	1.08 (0.70, 1.66)	Low DHOS exposure: 1.18 (0.80, 1.74); 0.39 High DHOS exposure: 1.56 (1.05, 2.32); 0.03

Measure of interaction on additive scale (Relative Excess Risk Due to Interaction (RERI)) (95% CI): Low Decline-Low DHOS Exposure RERI: 0.18 (−0.71, 1.07); High Decline-Low DHOS Exposure RERI: −0.38 (−1.35, 0.59); Low Decline-High DHOS Exposure RERI: 0.19 (−0.71, 1.09); High Decline-High DHOS Exposure RERI: −0.39 (−1.38, 0.60)

IRRs are adjusted for economic exposure to the DHOS, litter, education, income, race/ethnicity, social support, and time between DHOS and interview.

Abbreviations: Deepwater Horizon Oil Spill (DHOS); Women and Their Children's Health Study (WaTCH); Centers for Epidemiologic Studies Depression Scale (CES-D); Adjusted Incidence Rate Ratio (aIRR)

Bolded values indicate statistical significance.