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Research Article

Associations between direct contact with the oil and worsened health indicators after Deepwater Horizon oil spill: Results from Gulf States Population Survey

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Background

Oil spills were known to affect human health through the exposure of inherent hazardous chemicals. The aim of the study was to examine the associations between direct contact with the oil (DCO) and health indicators among the adult residents in the 25 coastal counties or parishes most directly affected by the Deepwater Horizon oil spill (DHOS) in the Gulf of Mexico.

Methods

Data were based on the Gulf States Population Survey (GSPS). The GSPS collected survey data from a random sample of households, with the majority of the interviews conducted in the 25 coastal counties or parishes that were most directly affected by the spill. After identifying the confounding variables, associations of DCO with poor quality of life (QoL), poor self-rated health (SRH), psychiatric disorders, asthma, and cardiovascular disease among the adult residents after DHOS were analyzed using logistic regressions.

Results

The mean age of total of 5,167 adult residents at the time of questionnaire completion was 53.93 (SD=16.29) ranging from 18 to 95 years. Controlling for confounding variables, DCO was associated with higher odds of poor mental QoL (adjusted odds ratio [aOR]: 1.284; 95% confidence interval [CI]: 1.045-1.578; *p*=.018), poor SRMH (aOR=1.278; 95%CI: 1.021-1.601; *p*=.033), anxiety (aOR=1.680; 95%CI: 1.395-2.024; *p*<.001), depression (aOR=1.182; 95%CI: 0.977-1.430; *p*=.086), and suicidality (aOR=1.920; 95%CI: 1.411-2.614; *p*<.001) after DHOS.

Conclusions

In conclusions, the prevalence of co-occurring poor SRHs, co-existing poor QoL, and concurrent psychiatric disorders was high in adult residents after DHOS. Similarly, DCO had association with poor mental QoL, poor SRMH, and psychiatric disorders. The empirical findings of this research presented the managerial implications in the field of environmental health.

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1. Introduction

After Deepwater Horizon oil spill (DHOS) in the Gulf of Mexico on the April 20, 2010, a substantial body of academic organizations and scholars focused on the negative health outcomes from the environmental catastrophe. For example, the Gulf States Population Survey (GSPS, https://www.cdc.gov/) organized by the Centers for Disease Control and Prevention in the United States were carried out. Recently, researchers had also reported that DHOS produced great catastrophic environmental pollution [1][2][3]. Likewise, environment scientists identified the relationship between toxic chemicals and environmental health[4][5][6][7]. Additionally, prolonged financial loss after the DHOS significantly predicted higher drug use, alcohol use, mood problems, and depressive symptoms [8]. Thus, several scholars thought DHOS as a unique opportunity to study potential adverse health effects [9].

Prior studies documented associations between crude oil exposures and adverse health outcomes among clean-up workers and United States Coast Guard personnel. For example, a study suggested that exposure to both crude oil and oil dispersant might result in acute neurological symptoms in a sample of U.S. Coast Guard responders [10]. Even worse, clean-up workers might increase the likelihoods of modest decreases in neurobehavioral function [11], low lung function [12], and nonfatal myocardial infarction (MI) [13]. But to date, few similar reports were from coastal adult residents after DHOS.

Before analyzing the associations between direct contact with the oil (DCO) and health indicators, several potential confounding variables should be identified. In some studies, quality of life (QoL) often was considered as a parallel outcome variable to self-rated health (SRH) [14][15]. Prior studies reported that chronic health conditions might correlate with health status. For example, a systematic review showed cardiovascular disease (CVD) spectra were associated with gradients of physical impairments [16]. Physical health indicators could predict CVD mortality among middle-aged and older people [17]. Self-rated physical health (SRPH) was a strong predictor of CVD incidence and death; similar self-rated mental health (SRMH) was not [18]. Moreover, the associations between psychiatric disorders and MI risk [19][20], the association between interpersonal emotional behaviors and physical health [21], and the association between outdoor pollutants and CVD [22] were reported. Chronic mental disorders, poor physical health-related QoL, and CVD risk might co-occur at a specific patient [23]. The changes in mental health (depressive symptoms and symptoms of mental distress) among women following the DHOS were reported [24]. Several studies reported the relationships among psychiatric disorders. For example, a study indicated that there was a significant and inverse relationship between posttraumatic growth and loneliness [25]. Another study indicated that higher levels of resilience and meaning together were predictive of fewer posttraumatic stress symptoms after controlling for the effect of the spill [26]. Thus, a specific health indicator could be a confounding variable when another health indicator had association with DCO.

As reviewed earlier, researchers have correlated DCO with adverse health outcomes. However, it was unclear how DCO was associated with worsened health indicators. Thus, the main research questions were below.

- Question 1: Controlling for confounding variables, how was DCO associated with poor QoLs?
- Question 2: Controlling for confounding variables, how was DCO associated with poor SRHs?
- Question 3: Controlling for confounding variables, how was DCO associated with psychiatric disorders?
- Question 4: Controlling for confounding variables, how was DCO associated with chronic health conditions?

This research focuses on the associations of interest. Thus, a public available dataset and main variables of interest were first explained. Subsequently, the associations of interest were explored with logistic regressions after screening out confounding variables. Finally, the empirical outcomes of this study were discussed from the perspectives of the theoretical and practical implications.

2. Materials and Methods

2.1. Data source

GSPS was a 12-month (December 15, 2010-December 16, 2011) survey of residents of four Gulf Coast states

(Alabama, Florida, Louisiana, and Mississippi) with landline telephone questionnaire. It was initiated to provide information about the mental and behavioral health status of the population in coastal areas most directly affected by DHOS. The GSPS collected survey data from a random sample of households, with the majority of the interviews conducted in the 25 coastal counties or parishes that were most directly affected by the spill. The survey was available in English and Spanish. Adults aged 18 years or older were included in the GSPS sample population if they resided in those four states and in one of 25 coastal counties that lay within 32 miles of areas closed to fishing. The GSPS used formulae adapted from the American Association of Public Opinion Research (AAPOR) and the Council of American Survey Research Organizations (CASRO) to calculate response rates. After calculation, overall GSPS response rates of CASRO and AAPOR were 32.7% and 44.2%, respectively. CASRO response rates in Alabama, Florida, Louisiana, and Mississippi were 32.4%, 33.8%, 31.9%, and 35.1%, respectively. AAPOR response rates in Alabama, Florida, Louisiana, and Mississippi were 44.6%, 47.0%, 43.0%, and 45.2%, respectively.

2.2. *Main variables*

Here, there were two variables reflecting environmental and economic effects of oil spill. They were DCO and income change, respectively. DCO was measured by the question: "Did you have direct contact with the oil from the Gulf oil spill?" Its response options were yes (=1) and no (=0). Income change was reflected by a question: "How did the Gulf oil spill affect your household income?" with the response options (decreased: 19.41%, increased: 2.72%, and no change: 77.87%). Thus, income change was grouped as not changed (=0) and changed (=1) groups.

Socio-demographic variables

Demographic characteristics include age (18-35, 36-50, 51-65, and 66 or above years old), gender (1=male; 0=female), marital status (married=1 and single=0: divorced, widowed, separated, never married, and a member of an unmarried couple), race (white, black: Black or African American, and composite: American Indian or Alaska Native, Asian, native Hawaiian or other, and Pacific Islander), employment status (employed: employed for wages and self-employed, unemployed: out of work for more than 1 year, out of work for less than 1 year, a homemaker, and a student, retired, and unable to work), and household income (low level: less than $20,000, middle level: $20,000 to less than $50,000, and high level: $50,000 or more).

Poor SRH

SRPH was measured by the question: "How would you rate your physical health?" SRMH was measured by the question: "How would you rate your mental health?" Self-rated general health (SRGH) was measured by the question: "How would you rate your general health?" Their response options were excellent (=1), very good (=2), good (=3), fair (=4), and poor (=5). Thus, poor SRPH, poor SRMH, and poor SRGH were recoded as yes (=1; fair and poor) and no (=0; excellent, very good, and good).

Psychiatric disorders

Here, psychiatric disorders included suicidality, high mastery, depression, and anxiety. Suicidality was measured by the question: "At any time in the past 12 months, did you seriously think about trying to kill yourself?" Their response options were yes (=1) and no (=0). Self-mastery was originated from Pearlin and Schooler's Mastery Scale (1978) [27] which was a 5-point Likert scale with response options from "strongly disagree" to "strongly agree" with Cronbach's alpha coefficient equal to 0.6356 and total score ranging from 16 to 25. Structural validity of the original Spanish translation of the Pearlin and Schooler's Mastery Scale (1978) in two groups of Spanish-speaking individuals receiving primary care at community clinics in Florida was evaluated [28]. Here, high mastery was defined as yes (=1) when total score from summing items was ≥ 15 and no (=0) when total score was < 15. Depression was measured by the question: "Has a doctor or other healthcare provider ever told you that you had a depressive disorder, including depression, dysthymia, or minor depression?" Anxiety was measured by the question: "Has a doctor or other healthcare provider ever told you that you had an anxiety disorder, including acute stress disorder, anxiety, generalized anxiety disorder, obsessive-compulsive disorder, panic disorder, phobia, posttraumatic stress disorder, or social anxiety disorder?" Their response options were yes (=1) and no (=0) to depression and anxiety in the sample.

Poor quality of life (QoL)

Poor physical QoL was measured by the question: "Now thinking about your physical health, which includes physical illness and injury, for about how

many days during the past 30 days was your physical health not good?" Poor mental QoL was measured by the question: "Now thinking about your mental health, which includes stress, depression, and problems with emotions, for how many days during the past 30 days was your mental health not good?" Their responses were days ranging from 0 to 30. Thus, poor QoLs could be recoded as yes (1=1 day and above) and no (0=0 day).

Chronic health conditions

Although many other diseases were known to have an impact on quality of life, only MI, coronary heart disease (CHD), and asthma were reported as chronic health conditions in the questionnaire. MI was measured by the question: "Has a doctor, nurse, or other health professional ever told you that you had a heart attack, also called a myocardial infarction?" CHD was measured by the question: "Has a doctor, nurse, or other health professional ever told you that you had angina or coronary heart disease?" Their response options were yes (=1) and no (=0).Thus, response options of CVD were yes (=1) if MI=1 or CHD=1 and no (=0) if MI=0 and CHD=0. Asthma was measured by the question: "Do you still have asthma?" Their response options were yes (=1) and no (=0).

2.3. Statistical Analysis

Adult residents' socio-demographic characteristics, poor SRH, poor QoL, and psychiatric disorders were compared by DCO using Chi-Square test. Regarding confounding factors in a stepwise fashion, the associations between DCO and poor QoLs, associations between DCO and poor SRHs, associations between DCO and psychiatric disorders, associations between DCO and chronic health conditions were assessed using logistic regression models. The relevant assumed causal diagrams with some conceptualized intermediates were too complex to depict various possible causal thinking. Thus, confnd command in Stata program was used to screen out potential confounding variables [29]. In order to identify the confounding variables in logistic regressions, the cut-off value 0.09% of change-in-estimate criterion was adopted[30][31]. For the sake of bias reduction, logistic regressions on the targeted associations with covariates were conducted by firthlogit program [32].

If DCO and income change appeared in a firthlogit regression as covariates, there might be mediating or moderating effects. Thus, Stata program medeff (logit) was adopted to explore mediation and confounding effects. After that, the moderating analysis could be performed and tested by the moderation models in Andrew F. Hayes' Process procedure for SPSS Release 2.13 (www.afhayes.com). Stata/MP 14.0 (StataCorp, College Station, TX) was used to perform all the statistical analysis except moderating analysis.

3. Results

3.1. Sample characteristics by DCO

As demonstrated in table 1, 25% of total adult residents were 66 and above years old. Considering gender, 70.76% of total adult residents were females. Regarding health indicators, the majority of respondents were of high mastery (88.8%), followed by asthma (67.37%), poor physical QoL (63.36%), poor mental QoL (57.88%), depression (38.56%), poor SRPH (35.6; 5 point scale: fair 22.32%, poor 13.70% N=5,292), anxiety (32.31%), poor SRGH (29.02%; 5 point scale: fair 19.20%, poor 10.02%, N=5,292), CVD (17.46%), poor SRMH (16.92%; 5 point scale: fair 12.68%, poor 4.58%, N=5,285), and suicidality (5.94%). There were significant DCO differences with respect to age group, sex, employment status, household income, poor SRMH, poor physical QoL, poor mental QoL, suicidality, anxiety, and depression.

	DCO		Chi-square	P value
	No (%)	Yes (%)		
Age group (N=5,100)			75.3680	0.000***
18-35	682(13.37%)	131(2.57%)		
36-50	956(18.75%)	160(3.14%)		
51-65	1,661(32.57%)	235(4.61%)		
66 or above	1,208(23.69%)	67(1.31%)		
Sex (N=5,167)			13.3400	0.000***
Female	3,267 (63.23%)	389 (7.53%)		
Male	1,296 (25.08%)	215 (4.16%)		
Marital status (N=5,140)				
Single	2,409 (46.87%)	307 (5.97%)	0.6132	0.434
Married	2,133 (41.50%)	291 (5.66%)		
Race (N= 5,159)			1.4729	0.479
White	3,361 (65.15%)	454 (8.80%)		
Black	904 (17.52%)	108 (2.09%)		
Composite	290 (5.62%)	42 (0.81%)		
Employment status (N= 5,150)			47.6902	0.000***
Employed	1,781(34.58%)	300(5.83%)		
Unemployed	762(14.80%)	113(2.19 %)		
Retired	1,242(24.12%)	90(1.75%)		
Unable to work	763(14.82%)	99(1.92%)		
Household income (N=4,353)			5.9993	0.050**
Low	1,077(24.74%)	146(3.35%)		
Middle	1,361(31.27%)	160(3.68%)		
High	1,394(32.02%)	215(4.94%)		
Poor SRPH (N=5,161)			0.2738	0.601
No	2,937 (56.91%)	382 (7.40%)		
Yes	1,621 (31.41%)	221 (4.28%)		
Poor SRMH (N=5,154)			9.8618	0.002***
No	3,809 (73.90%)	473 (9.18%)		
Yes	743 (14.42%)	129 (2.50%)		
Poor SRGH (N= 5,162)			0.5426	0.461
No	3,243 (62.82%)	421 (8.16%)		
Yes	1,315 (25.47%)	183 (3.55%)		
Poor physical QoL (N=5,057)			3.4055	0.065*

	DCO		Chi-square	P value
	No (%)	Yes (%)		
No	1,655 (32.73%)	198 (3.92%)		
Yes	2,806 (55.49%)	398 (7.86%)		
Poor mental QoL (N=5,086)			10.1267	0.001***
No	1,923 (37.81%)	214 (4.21%)		
Yes	2,568 (50.49%)	381 (7.49%)		
Suicidality (N=5,005)			17.5769	0.000***
No	4,183 (83.58%)	525 (10.48%)		
Yes	240 (4.80%)	57 (1.14%)		
High mastery (N=4,980)			1.4205	0.233
No	480 (9.64%)	73 (1.47%)		
Yes	3,919 (78.69%)	508 (10.20%)		
Anxiety (N=5,128)				
No	3,130 (61.04%)	341 (6.65%)	33.8158	0.000***
Yes	1,402 (27.34%)	255 (4.97%)		
Depression (N=5,145)				
No	2,825 (54.91%)	336 (6.53%)	8.4788	0.004***
Yes	1,720 (33.43%)	264 (5.13%)		
Asthma (N=5,167)				
No	1,501 (29.05%)	185 (3.58%)	1.2458	0.264
Yes	3,062 (59.26%)	419 (8.11%)		
CVD (N=5,109)			0.0078	0.930
No	3,725 (72.91%)	492 (9.63%)		
Yes	787 (15.40%)	105 (2.06%)		

Table 1. Characteristics of sample by DCO.

*Note: ***, **, and * indicated 0.01, 0.05, and 0.10 significance level, respectively.*

3.2. Associations between DCO and poor QoLs

Supplemental Table 1 showed that the change-in-estimates of were high mastery, poor SRMH, poor SRGH, and race equal to or less than 0.0796%, which indicated they were covariates. However, the change-in-estimates of depression, marital status, age group, CVD, poor mental QoL, income change, poor SRPH, household income, sex, asthma, suicidality, employment status, and anxiety were equal to or greater than 0.1397%, which indicated they were potential confounding variables. Because of being screened out as a potential confounding variable, income change could not be considered as a mediator or moderator in the association between DCO and poor physical QoL.

In Table 2, controlling for depression, marital status, age group, CVD, poor mental QoL, income change, poor SRPH, household income, sex, asthma, suicidality, employment status, and anxiety, high mastery (aOR=0.776; 95%CI: 0.599-1.004; p=.054), poor SRMH (aOR=1.800; 95%CI: 1.409-2.301; p<.001),

poor SRGH (aOR=8.801; 95%CI: 7.072-10.953; p<.001), and black race (aOR=1.267; 95%CI: 1.074-1.495; p=.005) had significant associations with poor physical QoL.

Supplemental Table 2 showed that the change-in-estimates of depression, household income, and marital status were equal to or less than 0.0028%, which indicated they were covariates. However, the change-in-estimates of poor SRPH, asthma, high mastery, employment status, CVD, race, poor SRGH, poor physical QoL, sex, poor SRMH, suicidality, age group, anxiety, and income change were equal to or greater than 0.1716%, which indicated they were potential confounding variables. Thus, income change was not applicable for a mediator or moderator in the association between DCO and poor mental QoL.

In Table 2, controlling for poor SRPH, asthma, high mastery, employment status, CVD, race, poor SRGH, poor physical QoL, sex, poor SRMH, suicidality, age group, anxiety, and income change, DCO (aOR=1.284; 95%CI: 1.045-1.578; p=.018), depression (aOR=4.284; 95%CI: 3.713-4.944; p<.001), middle household income (aOR=0.700; 95%CI: 0.587-0.835; p<.001), and high household income (aOR=0.598; 95%CI: 0.496-0.722; p<.001) had significant associations with poor mental QoL.

	Poor physical QoL		Poor mental QoL	
	aOR(95% CI)	P value	aOR(95% CI)	P value
DCO	Ref.=No		Ref.=No	
Yes	1.158 (0.949-1.413)	0.150	1.284 (1.045-1.578)	0.018**
High mastery	Ref.=No			
Yes	0.776 (0.599-1.004)	0.054*		
Poor SRMH	Ref.=No			
Yes	1.800 (1.409-2.301)	0.000***		
Poor SRGH	Ref.=No			
Yes	8.801 (7.072-10.953)	0.000***		
Race	Ref.=White			
Black	1.267 (1.074-1.495)	0.005***		
Composite	1.053 (0.808-1.373)	0.702		
Depression			Ref.=No	
Yes			4.284 (3.713-4.944)	0.000***
Household income			Ref.= Low	
Middle			0.700 (0.587-0.835)	0.000***
High			0.598 (0.496-0.722)	0.000***
Marital status			Ref.= Single	
Married			0.901 (0.779-1.043)	0.164
Constant	1.229 (0.948-1.594)	0.120	1.228 (1.063-1.420)	0.005***
Number of observation	4,873		4,272	

Table 2. Associations of DCO with poor QoLs, aOR(95%CI).

*Note: ***, **, and * indicated 1%, 5%, and 10% significance level, respectively.*

3.3. Associations between DCO and poor SRHs

Supplemental Table 3 showed that the change-in-estimates of age group, poor mental QoL, and suicidality were equal to or less than 0.0871%, which indicated they were covariates. However, the change-in-estimates of depression, race, high mastery, marital status, CVD, poor SRGH, sex, asthma, household income, anxiety, poor physical QoL, poor SRMH, employment status, and income change were equal to or greater than 0.1504%, which indicated they were potential confounding variables. Thus, income change could not be considered as a mediator or moderator in the association between DCO and poor SRPH.

In Table 3, controlling for depression, race, high mastery, marital status, CVD, poor SRGH, sex, asthma, household income, anxiety, poor physical QoL, poor SRMH, employment status, and income change, age group: 36-50 (aOR=2.111; 95%CI: 1.687-2.643; p<.001), age group: 51-65 (aOR=3.194; 95%CI: 2.595-3.932; p<.001), age group: 66 or above (aOR=3.628; 95%CI: 2.900-4.540; p<.001), poor mental QoL (aOR=3.235; 95%CI: 2.822-3.707; p<.001), and suicidality (aOR=2.623; 95%CI: 2.023-3.402; p<.001) had significant associations with poor SRPH.

Supplemental Table 4 showed that the change-in-estimates of asthma, sex, and poor mental QoL were equal to or less than 0.0462%, which indicated they were covariates. However, the change-in-estimates of employment status, race, marital status, poor physical QoL, high mastery, CVD, poor SRPH, age group, household income, anxiety, depression, poor SRGH, suicidality, and income change were equal to or greater than 0.1753%, which indicated they were potential confounding variables. Thus, income change could not be considered as a mediator or moderator in the association between DCO and poor SRMH.

In Table 3, controlling for employment status, race, marital status, poor physical QoL, high mastery, CVD, SRPH, age group, household income, anxiety, depression, poor SRGH, suicidality, and income change, DCO (aOR=1.278; 95%CI: 1.021-1.601; p=.033), asthma (aOR=1.751; 95%CI: 1.457-2.104; p<.001), and poor mental QoL (aOR=12.844; 95%CI: 9.775-16.876; p<.001) had significant associations with poor SRMH.

Supplemental Table 5 showed that the change-in-estimate of race was equal to 0.0658%, which indicated they were covariates. However, the change-in-estimates of poor mental QoL, sex, asthma, marital status, depression, household income, suicidality, age group, high mastery, poor SRPH, anxiety, CVD, poor physical QoL, poor SRMH, employment status, and income change were equal to or greater than 0.1332%, which indicated they were potential confounding variables. Thus, income change could not be considered as a mediator or moderator in the association between DCO and poor SRGH.

In Table 3, controlling for poor mental QoL, sex, asthma, marital status, depression, household income, suicidality, age group, high mastery, poor SRPH, anxiety, CVD, poor physical QoL, poor SRMH, employment status, and income change, black race (aOR=1.322; 95%CI: 1.140-1.534; p<.001) and composite race (aOR=1.270; 95%CI: 0.999-1.614; p=.051) had significant associations with poor SRGH.

	Poor SRPH		Poor SRMH		Poor SRGH	
	aOR(95% CI)	P value	aOR(95% CI)	P value	aOR(95% CI)	P value
DCO	Ref.=No		Ref.=No		Ref.=No	
Yes	1.046 (0.860-1.273)	0.650	1.278(1.021-1.601)	0.033**	1.078(0.896-1.297)	0.428
Age group	Ref.=18-35					
36-50	2.111 (1.687-2.643)	0.000***				
51-65	3.194 (2.595-3.932)	0.000***				
66 or above	3.628 (2.900-4.540)	0.000***				
Poor mental QoL	Ref.=No		Ref.=No			
Yes	3.235 (2.822-3.707)	0.000***	12.844(9.775-16.876)	0.000***		
Suicidality	Ref.=No					
Yes	2.623 (2.023-3.402)	0.000***				
Sex			Ref.=Female			
Male			1.045(0.873-1.251)	0.631		
Asthma			Ref.=No			
Yes			1.751(1.457-2.104)	0.000***		
Race					Ref.=White	
Black					1.322(1.140-1.534)	0.000***
Composite					1.270(0.999-1.614)	0.051*
Constant	0.096 (0.078-0.119)	0.000***	0.018(0.014-0.025)	0.000***	0.377(0.350-0.406)	0.000***
Number of observation	4,862		5,077		5,154	

Table 3. Associations of DCO with poor SRHs, AOR(95%CI).

*Note: ***, **, and * indicated 1%, 5%, and 10% significance level, respectively.*

3.4. Associations between DCO and psychiatric disorders

Supplemental Table 6 showed that the change-in-estimates of poor SRPH, marital status, and high mastery were equal to or less than 0.0356%, which indicated they were covariates. However, the change-in-estimates of race, SRGH, sex, poor SRMH, poor mental QoL, CVD, asthma, household income, poor physical QoL, depression, age group, employment status, suicidality, and income change were equal to or greater than 0.2163%, which indicated they were potential confounding variables. Thus, income change could not be considered as a mediator or moderator in the association between DCO and anxiety.

In Table 4, controlling for race, poor SRGH, sex, poor SRMH, poor mental QoL, CVD, asthma, household income, poor physical QoL, depression, age group, employment status, suicidality, and income change, DCO (aOR=1.680; 95%CI: 1.395-2.024; p<.001), poor SRPH (aOR=2.596; 95%CI: 2.280-2.955; p<.001), married status (aOR=0.772; 95%CI: 0.681-0.876; p<.001), and high mastery (aOR=0.561; 95%CI: 0.464-0.679; p<.001) had significant associations with anxiety.

Supplemental Table 7 showed that the change-in-estimates of poor mental QoL, poor SRGH, marital status, and asthma were equal to or less than 0.0660%, which indicated they were covariates. However, the change-in-estimates of high mastery, household income, poor SRPH, age group, poor physical QoL, income change, race, CVD, sex, suicidality, employment status, poor SRMH, and anxiety were equal to or greater than 0.109, which indicated they were potential confounding variables. Thus, income change could not be considered as a mediator or moderator in the association between DCO and depression.

In Table 4, controlling for high mastery, household income, poor SRPH, age group, poor physical QoL, income change, race, CVD, sex, suicidality, employment status, poor SRMH, and anxiety, DCO (aOR=1.182; 95%CI: 0.977-1.430; p=.086), married status (aOR=0.866; 95%CI: 0.764-0.982; p=.025), poor mental QoL (aOR=3.913; 95%CI: 3.419-4.478; p<.001), poor SRGH (aOR=2.576; 95%CI: 2.247-2.953; p<.001), and asthma (aOR=1.257; 95%CI: 1.098-1.440; p=.001) had significant associations with depression.

Supplemental Table 8 showed that the change-in-estimates of poor SRGH and poor SRPH were equal to or less than 0.0017%, which indicated they were covariates. However, the change-in-estimates of asthma, age group, CVD, race, sex, poor mental QoL, employment status, poor SRMH, marital status, poor physical QoL, depression, high mastery, household income, anxiety, and income change were equal to or greater than 0.1534%, which indicated they were potential confounding variables. Thus, income change could not be considered as a mediator or moderator in the association between DCO and suicidality.

In Table 4, controlling for asthma, age group, CVD, race, sex, poor mental QoL, employment status, poor SRMH, marital status, poor physical QoL, depression, high mastery, household income, anxiety, and income change, DCO (aOR=1.920; 95%CI: 1.411-2.614; p<.001), poor SRGH (aOR=2.861; 95%CI: 1.978-4.137; p<.001), and poor SRPH (aOR=1.518; 95%CI: 1.044-2.207; p=.029) had significant associations with suicidality.

Supplemental Table 9 showed that the change-in-estimates of race and poor physical QoL were equal to or less than 0.0172%, which indicated they were covariates. However, the change-in-estimates of marital status, asthma, CVD, poor mental QoL, depression, sex, poor SRPH, household income, poor SRGH, poor SRMH, age group, anxiety, suicidality, employment status, and income change were equal to or greater than 0.0950%, which indicated they were potential confounding variables. Thus, income change could not be considered as a mediator or moderator in the association between DCO and high mastery.

In Table 4, controlling for marital status, asthma, CVD, poor mental QoL, depression, sex, poor SRPH, household income, poor SRGH, poor SRMH, age group, anxiety, suicidality, employment status, and income change, black race (aOR=0.782; 95%CI: 0.630-0.972; p=.026) and poor physical QoL (aOR=0.350; 95%CI: 0.279-0.439; p<.001) had significant associations with high mastery.

	Anxiety		Depression		Suicidality		High mastery	
	aOR(95% CI)	P value	aOR(95% CI)	P value	aOR(95% CI)	P values	aOR(95% CI)	P value
DCO	Ref.=No		Ref.=No		Ref.=No		Ref.=No	
Yes	1.680(1.395-2.024)	0.000***	1.182(0.977-1.430)	0.086*	1.920(1.411-2.614)	0.000***	0.856(0.656-1.116)	0.250
Poor SRPH	Ref.=No							
Yes	2.596(2.280-2.955)	0.000***						
Marital status	Ref.= Single		Ref.= Single					
Married	0.772(0.681-0.876)	0.000***	0.866(0.764-0.982)	0.025**				
High mastery	Ref.=No							
Yes	0.561(0.464-0.679)	0.000***						
Poor mental QoL			Ref.=No					
Yes			3.913(3.419-4.478)	0.000***				
Poor SRGH			Ref.=No		Ref.=No			
Yes			2.576(2.247-2.953)	0.000***	2.861(1.978-4.137)	0.000***		
Poor SRPH					Ref.=No			
Yes					1.518(1.044-2.207)	0.029**		
Race							Ref.=White	
Black							0.782(0.630-0.972)	0.026**
Composite							0.776(0.548-1.098)	0.152
Poor physical QoL							Ref.=No	
Yes							0.350(0.279-0.439)	0.000***
Asthma			Ref.=No					
Yes			1.257(1.098-1.440)	0.001***				
Constant	0.579(0.472-0.710)	0.000	0.178(0.152-0.209)	0.000***	0.030(0.025-0.037)	0.000***	18.655(15.090-23.063)	0.000***
Number of observation	4,913		5,034		4,996		4,884	

Table 4. Associations of DCO with psychiatric disorders, aOR(95%CI).

*Note: ***, **, and * indicated 1%, 5%, and 10% significance level, respectively.*

3.5. Associations between DCO and chronic health conditions

Supplemental Table 10 showed that the change-in-estimates of high mastery, marital status, race, and depression were equal to or less than 0.0294%, which indicated they were covariates. However, the change-in-estimates of poor mental QoL, asthma, household income, poor SRMH, suicidality, poor physical QoL, poor SRPH, sex, poor SRGH, anxiety, employment status, income change, and age group were equal to or greater than 0.1407%, which indicated they were potential confounding variables. Thus, income change could not be considered as a mediator or moderator in the association between DCO and CVD.

In Table 5, controlling for poor mental QoL, asthma, household income, poor SRMH, suicidality, poor physical QoL, poor SRPH, sex, poor SRGH, anxiety, employment status, income change, and age group, high mastery (aOR=0.521; 95%CI: 0.423-0.641; p<.001), married status (aOR=0.775; 95%CI: 0.663-0.906; p=.001), and depression (aOR=1.578; 95%CI: 1.353-1.840; p<.001) had significant associations with CVD.

Supplemental Table 11 showed that the change-in-estimates of high mastery, poor SRGH, poor SRMH, depression, race, marital status, and poor mental QoL were equal to or less than 0.0745%, which indicated they were covariates. However, the change-in-estimates of employment status, suicidality, CVD, poor SRPH, poor physical QoL, sex, anxiety, age group, income change, and household income were equal to or greater than 0.4245%, which indicated they were potential confounding variables. Thus, income change could not be considered as a mediator or moderator in the association between DCO and asthma.

In Table 5, controlling for employment status, suicidality, CVD, poor SRPH, poor physical QoL, sex, anxiety, age group, income change, and household income, high mastery (aOR=0.767; 95%CI: 0.611-0.963; p=.022), poor SRGH (aOR=1.929; 95%CI: 1.632-2.279; p<.001), depression (aOR=1.275; 95%CI: 1.108-1.467; p=.001), black race (aOR=1.189; 95%CI: 1.011-1.398; p=.037), and married status (aOR=0.825; 95%CI: 0.728-0.935; p=.003) had significant associations with asthma.

	CVD		Asthma	
	aOR(95% CI)	P value	aOR(95% CI)	P value
DCO	Ref.=No		Ref.=No	
Yes	0.986(0.780-1.246)	0.905	1.105(0.910-1.340)	0.314
Marital status	Ref.=Single		Ref.=Single	
Married	0.775(0.663-0.906)	0.001***	0.825(0.728-0.935)	0.003***
Race	Ref.= White		Ref.= White	
Black	1.085(0.896-1.314)	0.402	1.189(1.011-1.398)	0.037**
Composite	1.244(0.928-1.667)	0.145	1.026(0.794-1.325)	0.844
Poor SRGH			Ref.=No	
Yes			1.929(1.632-2.279)	0.000***
Poor SRMH			Ref.=No	
Yes			1.070(0.866-1.323)	0.529
Poor mental QoL			Ref.=No	
Yes			1.026(0.899-1.172)	0.705
Depression	Ref.=No		Ref.=No	
Yes	1.578(1.353-1.840)	0.000***	1.275(1.108-1.467)	0.001***
High mastery	Ref.=No		Ref.=No	
Yes	0.521(0.423-0.641)	0.000***	0.767(0.611-0.963)	0.022**
Constant	0.326(0.258-0.410)	0.000***	2.041(1.584-2.630)	0.000***
Number of observation	4,875		4,860	

Table 5. Associations of DCO with diseases, aOR(95%CI).

*Note: ***, **, and * indicated 1%, 5%, and 10% significance level, respectively.*

4. Discussion

4.1. Statement of principal findings

Statistically, most of the surveyed residents were contracted by poor physical QoL, poor mental QoL, high mastery, and asthma. Controlling for confounding variables, DCO might not be a risk factor for poor physical QoL, poor SRPH, poor SRGH, high mastery, CVD, and asthma but be a risk factor for poor mental QoL, poor SRMH, anxiety, depression, and suicidality. In particular, income change did not mediate or moderate associations between DCO and worsened health indicators.

Regarding socioeconomic factors, age increase might increase the likelihood of poor SRPH. Likewise, Black race might increase the likelihoods of poor physical QoL, poor SRGH, high mastery, and asthma. Meanwhile, composite race was associated with increased risks for poor SRGH. Married status could protect them from anxiety, depression, CVD, and asthma. Additionally, higher household income indicated lower risk of poor mental QoL.

With respect to self-rated health, poor SRMH was associated with increased risks for poor physical QoL. Likelihoods of poor SRGH might be observed higher among the persons with poor physical QoL, depression, suicidality, and asthma. Similarly, poor

SRPH was associated with increased risks for anxiety and suicidality.

With regard to psychiatric disorders, high mastery could decrease the prevalence of poor physical QoL, anxiety, CVD, and asthma. In addition, depression was associated with high likelihoods of poor mental QoL and asthma, and a low likelihood of CVD. Moreover, suicidality was associated with increased risks for SRPH. Additionally, asthma was associated with increased risks for poor SRMH and depression.

In the case of QoL, persons who reported poor mental QoL were still more likely to report poor SRPH, poor SRMH, and depression than those who did not. Particularly, poor physical QoL was associated with decreased risks for high mastery.

4.2. Interpretation within the context of the wider literature

Regarding the role of DCO, the findings in this study were in line with several other studies. For example, analyzing the GSPS survey data, a study concluded oil contact was associated with increased depression severity [33]. Likewise, a study concluded DHOS exposure might be a risk factor for illness anxiety but not more general behavioral health concerns [34]. Analysis of the GSPS data also showed that differences in individual characteristics and direct or indirect exposure to the disaster drove the individual-level variation in health outcomes (mental distress, physical distress, and depression) [35].

Psychiatric disorders associated with DCO possibly were caused by resource loss attributed to the spill [36], financial hardship and disaster-related damages [37], and proximity to the shoreline [38].

Inconsistent with prior studies, this study did not conclude the association between DCO and physical health change. Notably, strong relationships between oil and oil dispersant exposures and acute respiratory symptoms [39] and positive associations between crude oil exposure and various acute physical symptoms including asthma [40] were reported.

Regarding mental health, these findings from this study were in line with several previous studies. Several early studies confirmed that DCO could predict poor mental health outcomes [41][42] among the coastal residents. Meanwhile, physical health symptoms contributed to cleanup workers' risk for mental health symptoms [43]. A study in East Asian also concluded mental health was associated with levels of perceived environmental pollution [44].

Regarding co-existing symptoms, the findings from this study were in accord with those from previous studies. For instance, the association between SRH and health-related QoL dimensions also was demonstrated in patients with rheumatoid arthritis [45]. An empirical study in the United States highlighted socioeconomic gap in health due to exposure to air pollutants from large industrial facilities [46]. The health gap could be explained partly by the different levels of exposure to air pollution and inequality in health effects [47].

Regarding chronic health conditions risk, the findings in this study were not in line a prior study. Thus, an epidemiological study ascertained heart attack risk (self-reported physician-diagnosed myocardial infarction, or fatal coronary heart disease) during the study period (2010-2016) among 24,375 oil spill workers [48]. Chronic health conditions were possibly not the resultant events of DCO. This study described a population with high health vulnerability exposed to an environmental hazard and assessed the consequential health effects of an environmental hazard. Simultaneously, self-reported diagnosed outcomes prior to the oil spill could influence the targeted associations. But, the questions related to the main chronic diseases did not provide the information whether the diagnoses were before or after the oil spill.

4.3. Implications for policy, practice, and research

With respect to health service intervention, public health assessments of environmental disaster should rely on functional patient-reported outcomes. The co-occurrence of severe mental illness and poor physical health might partly be the outcome of their interactions with environmental drivers. Although there were several elements contributing to mortality and morbidity among these CVD adult residents as compared with the general population, risk factors from environmental disaster were of particular significance. Consistent with two early studies [49] [50], the findings in this study highlighted the importance of epidemiologic investigation of potential adverse health effects of the oil spill and psychological resilience in long-term disaster recovery.

4.4. Limitations

Some limitations of this study need to be acknowledged. In GSPS, cross-sectional nature and self-reported data rather than clinical health data could not reflect the tagarted causal relationships scientifically and clinically. Especially, self-reported data were subject to recall biases which were hardly overcome in cross-sectional analysis. A second limitation of this study was the possible over-report. Due to self-protection and need of compensation, the respondents might deviate from the real facts when answering the questionnaire, especially for the persons who were depressed or in poor health over-reported exposures. Several studies confirmed the inference. For example, a clinical study demonstrated that severe post-spill mental health symptoms were positively associated with counseling and medication use [51]. Another study concluded that a lack of information and trust in government agencies exacerbated negative perceptions of oil spill-related dangers [52]. Besides, firthlogit program only could allow convergence to finite estimates in cases of separation in logistic regression. The program could not eliminate the testing biases caused by self-reported survey.

5. Conclusions

In conclusion, co-existing prevalence of poor SRHs, poor QoL, and psychiatric disorders was high in adult residents after DHOS. This study confirmed the significant associations of DCO with poor mental QoL, poor SRMH, and psychiatric disorders. Some potential confounding variables were confirmed to play a minor part in the associations of interest. Regarding the treatment of co-occurring symptoms and comorbidities, clinicians should explicitly focus on mental health care in coastal adult residents. Consequently, the results and the findings of the current study contributed to the knowledge of health management after DHOS. The findings were also meaningful for specific targeted adult residents.

Abbreviations

- DHOS = Deepwater Horizon oil spill
- DCO = direct contact with the oil
- CVD = cardiovascular disease
- MI = myocardial infarction
- CHD = coronary heart disease
- GSPS = Gulf States Population Survey
- poor SRH = poor self- rated health
- poor SRPH = poor self-rated physical health
- poor SRMH = poor self-rated mental health
- poor SRGH = poor self-rated general health
- poor physical QoL = poor physical quality of life
- poor mental QoL = poor mental quality of life
- 95%CI = 95% Confidence Interval
- aOR = adjusted odds ratio

Supplementary Materials

The following supporting information can be downloaded at: here, Table S1: Change-in-estimate for poor physical QoL with possible confounding factors; Table S2: Change-in-estimate for poor mental QoL with possible confounding factors; Table S3: Change-in-estimate for poor SRPH with possible confounding factors; Table S4: Change-in-estimate for poor SRMH with possible confounding factors; Table S5: Change-in-estimate for poor SRGH with possible confounding factors; Table S6: Change-in-estimate for anxiety with possible confounding factors; Table S7: Change-in-estimate for depression with possible confounding factors; Table S8: Change-in-estimate for suicidality with possible confounding factors; Table S9: Change-in-estimate for high mastery with possible confounding factors; Table S10: Change-in-estimate for CVD with possible confounding factors; Table S11: Change-in-estimate for asthma with possible confounding factors.

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Declarations

Author Contributions

BXH designed, read, polished, revised, and approved the final manuscript. Both authors have read and approved the final manuscript.

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Conflicts of Interest

The authors declare that they have no competing interests regarding the publication of this paper. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Institutional Review Board Statement

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Data Availability Statement

Access to the survey data is open and publicly available in the following link. https://stacks.cdc.gov/view/cdc/32295/Share

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