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Self-reported myocardial infarction and fatal coronary heart disease among oil spill workers and community members 5 years after *Deepwater Horizon*

Jean Strelitz[a,*], Alexander P. Keil[a], David B. Richardson[a], Gerardo Heiss[a], Marilie D. Gammon[a], Richard K. Kwok[b], Dale P. Sandler[b], Lawrence S. Engel[a,b]

[a] Department of Epidemiology, University of North Carolina at Chapel Hill, Gillings School of Global Public Health, 135 Dauer Drive, 2101 McGavran-Greenberg Hall, Chapel Hill, NC 27599, USA
[b] National Institute of Environmental Health Sciences, NIH, DHHS, 111 T.W. Alexander Drive, Research Triangle Park, NC 27709, USA

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ABSTRACT

Background: Chemical, physical and psychological stressors due to the 2010 *Deepwater Horizon* oil spill may impact coronary heart disease (CHD) among exposed populations. Using longitudinal information from two interviews in the Gulf Long Term Follow-up (GuLF) STUDY, we assessed CHD among oil spill workers and community members.

Objective: To assess the associations between duration of oil spill clean-up work, residential proximity to the oil spill, and incidence of self-reported myocardial infarction or fatal CHD.

Methods: Among respondents with two GuLF STUDY interviews (n = 21,256), there were 395 first incident heart disease events (self-reported myocardial infarction or fatal CHD) across 5 years. We estimated hazard ratios (HR) and 95% confidence intervals (95%CI) for associations with duration of oil spill clean-up work and residential proximity to the oil spill. To assess potential impacts of non-response, we compared covariate distributions for those who did (n = 21,256) and did not (n = 10,353) complete the second interview and used inverse probability (IP) of censoring weights to correct for potential non-response bias.

Results: Living in proximity to the oil spill (vs. living further away) was associated with heart disease, with [HR (95%CI) = 1.30(1.01–1.67)] and without [1.29(1.00–1.65)] censoring weights. For work duration, hazard of heart disease appeared to be higher for those who worked > 180 days (vs. 1–30 days), with and without censoring weights [1.43(0.91–2.25) and 1.36(0.88–2.11), respectively]. Associations persisted throughout the 5-year follow-up.

Conclusions: Residential proximity to the spill and duration of clean-up work were associated with a suggested 29–43% higher hazard of heart disease events. Associations were robust to censoring.

1. Introduction

The 2010 *Deepwater Horizon* oil disaster was the largest marine oil spill in history. The spill began April 20th, 2010 when the *Deepwater Horizon* drilling rig exploded and sunk. Over 200 million gallons of crude oil were released into the Gulf of Mexico in the following months. The oil spill response and clean-up, which involved more than 100,000 workers, began at the start of the oil spill and continued through the end of 2010 (Kwok et al., 2017a).

During the oil spill response and clean-up, workers may have faced physical stress as well as chemical exposures from hydrocarbons volatilizing from fresh oil, combustion products from burning crude oil and flaring of natural gas, emissions from the equipment and machinery used during the clean-up, and chemical dispersants (Kwok et al., 2017a; Middlebrook et al., 2012; Stewart et al., 2018). Exposures to some of these pollutants, including particulate matter and volatile organic chemicals, have shown associations with risk of coronary heart disease (CHD) in environmental and occupational exposure studies (Bahadar et al., 2014; Brook et al., 2010; Peters, 2005; Stewart et al., 2018). Airborne particulate levels during the oil spill were elevated in coastal communities and around clean-up sites compared to typical ambient levels in these regions (Nance et al., 2016).

Apart from chemical exposures related to the spill, Gulf Coast communities faced economic burdens and increases in psychosocial

* Correspondence to: Department of Epidemiology, University of North Carolina at Chapel Hill, Gillings School of Global Public Health, 135 Dauer Drive, 2101 McGavran-Greenberg Hall, Campus Box 7435, Chapel Hill, NC 27599, USA.
E-mail address: Jean.Strelitz@mrc-epid.cam.ac.uk (J. Strelitz).

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stress in the wake of the oil spill (Gould et al., 2015; Peres et al., 2016). Local industries including fishing and tourism were disrupted for months following the spill (Shultz et al., 2015), and loss of income may have contributed to psychosocial stress in these communities. Psychosocial stress can impact risk of cardiovascular diseases by accelerating progression of atherosclerotic plaques (Rozanski et al., 1999). Thus, the physical and emotional stress caused by the oil spill may have contributed to an increased risk of CHD.

It is unknown whether exposures to pollutants or physical stressors during the oil spill may affect risk of heart disease over time. Short-term increases in ambient particulate matter concentrations increase risk of cardiovascular events and overall mortality acutely, but the persistence of these associations remains unexplored (Brook and Rajagopalan, 2010; Brook et al., 2010). A study of the *Prestige* oil spill found that respiratory symptoms among clean-up workers persisted up to 5 years after the spill (Zock et al., 2012). Studies of *Hebei Spirit* oil spill workers (Gwack et al., 2012) and United States Coast Guard deployed to work on the *Deepwater Horizon* spill (Alexander et al., 2018) have shown that longer durations of oil spill work were associated with increased respiratory symptoms. Despite the reported associations between oil spill work and persistent respiratory effects, no research has assessed incidence of cardiovascular diseases or other chronic health outcomes among oil-exposed populations.

The Gulf Long Term Follow-up (GuLF) STUDY is the largest study of the health impact of oil spills (Kwok et al., 2017a) and is the first study to assess heart disease among individuals exposed to oil spills. We have used longitudinal information from the GuLF STUDY to assess associations between duration of clean-up work, living in proximity to the oil spill, and self-reported myocardial infarction and fatal coronary heart disease up to 5 years after the oil spill. We also assessed predictors of non-response to the GuLF STUDY second interview and accounted for this attrition in our analyses.

2. Methods

2.1. Study population

The GuLF STUDY is a prospective cohort study of individuals who worked on, or had trained to work on, clean-up of the 2010 *Deepwater Horizon* oil spill (Kwok et al., 2017a). Participants in the study include individuals aged ≥ 21 years who completed mandatory oil spill safety training in order to take part in the oil spill response and clean-up as well as government workers and oil industry professionals who were living in the United States at the time of enrollment.

Recruitment began approximately 11 months after the start of the oil spill, in March 2011, and continued until May 2013. From a list of 62,803 presumably unique names with sufficient contact information, a total of 32,608 participants were enrolled and completed the first study interview. Of the enrolled participants, we excluded from the present analyses 999 individuals who completed a Vietnamese language abbreviated version of the questionnaire that did not collect complete information on oil spill clean-up jobs. Of the 31,609 participants who enrolled in the study and completed the full interview, 21,256 (67%) completed a second telephone interview in 2014–2016, two to three years after their first interview.

2.2. Exposure and outcome measures

All oil spill-related exposures and clean-up tasks were assessed during the first interview. Health outcomes were assessed during the first and second interviews. The exposures of interest in this report are duration of participation in oil spill clean-up work and home residence in an area proximal to the oil spill. Dates of initiating and ending clean-up work were self-reported by participants, as was their county or parish of residence at the time of enrollment. Work duration was defined categorically, based on the distribution of duration of oil spill work, as 1–30 days, 31–90 days, 91–180 days and > 180 days. Analyses of work duration included clean-up workers only, whereas analyses of residential proximity to the oil spill included both workers and nonworkers. Residential proximity to the oil spill was defined as "direct or indirect" for participants living in or adjacent to a county that had coastline oiled from the spill and "away from the spill" for participants living elsewhere in the Gulf region or in another part of the US. We grouped coastal and adjacent counties because these areas were likely to have been similarly impacted by loss of income and community stress due to the oil spill, and living in or adjacent to a county affected by the oil spill was associated with mental health symptoms following the spill (Kwok et al., 2017b).

The outcome of interest is the incident occurrence of a first heart disease event, defined as a self-reported myocardial infarction (MI), or a fatal CHD event ascertained from death certificates. During the first and second interviews, participants were asked if they had ever received a diagnosis of a heart attack or MI and, if so, the month and year of their first MI diagnosis. Participants who reported an MI occurring before clean-up work (n = 610) were excluded from the analyses.

Deaths due to CHD were ascertained from the National Death Index (NDI) for the entire enrolled cohort through December 31st, 2014, the latest date for which complete NDI data were available. International Classification of Diseases, 10th Edition (ICD-10) codes indicating ischemic heart disease as a cause of death (I20-I25) were counted as fatal CHD cases.

2.3. Risk period for heart disease events

The time at risk for a heart disease event was based on calendar time and was determined differently for analyses including all study participants and for analyses among clean-up workers only. For analyses of residential proximity to the spill and heart disease, participants were at risk for a self-reported first MI from the date that the oil spill began (April 20th, 2010); for analyses of work duration and heart disease, the risk period began at initiation of oil spill clean-up work, which was between April and July 2010 for most participants. For all analyses, the risk period for a self-reported MI ended at the earlier of the date of diagnosis of a first MI or the last GuLF STUDY interview that the participant completed. The risk period for a fatal CHD event began at the time of the enrollment interview, as participants had to be living to enroll in the study, and continued until December 31st, 2014. Only a participant's first reported MI diagnosis or CHD event was counted in this study.

2.4. Statistical methods

2.4.1. Censoring and predictors of loss to follow-up

Nonfatal MIs were censored if a participant who was at risk for a first MI, i.e. did not report an MI at the first interview, did not complete the second interview. We compared distributions of a broad range of factors plausibly related to the outcome and non-response, between those who did and did not complete the second interview. The factors that we assessed, determined by literature review and dependent on availability of data, included demographic (age; gender; ethnicity), lifestyle (cigarette smoking; alcohol consumption) and socioeconomic (income; education; employment status) covariates, as well as factors related to health at enrollment (prevalent myocardial infarction; prevalent hypertension; perceived health), and oil spill clean-up work characteristics (working on clean-up; duration of clean-up work; clean-up job type; exposure to burning oil; exposure to total hydrocarbons; and residential proximity to the oil spill.) We compared crude proportions of censoring across levels of each predictor variable. The magnitude and precision of these estimates were considered in order to assess the ability of each variable to predict non-response.

To describe the major predictors of non-response in our study, we fit a logistic regression model combined with a Least Absolute Shrinkage