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The deepwater horizon oil spill coast guard cohort study: A cross-sectional study of acute respiratory health symptoms

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ABSTRACT

Introduction: Over 8500 United States Coast Guard (USCG) personnel were deployed in response to the Deepwater Horizon (DWH) oil spill; however, human respiratory effects as a result of spill-related exposures are relatively unknown.

Methods: USCG personnel who responded to the DWH oil spill were queried via survey on exposures to crude oil and oil dispersant, and acute respiratory symptoms experienced during deployment. Adjusted log binomial regressions were used to calculate prevalence ratios (PRs) and 95% confidence intervals (CI), investigating the associations between oil spill exposures and respiratory symptoms.

Results: 4855 USCG personnel completed the survey. More than half (54.6%) and almost one-fourth (22.0%) of responders were exposed to crude oil and oil dispersants, respectively. Coughing was the most prevalent symptom (19.4%), followed by shortness of breath (5.5%), and wheezing (3.6%). Adjusted analyses showed an exposure-response relationship between increasing deployment duration and likelihood of coughing, shortness of breath, and wheezing in the pre-capping period. A similar pattern was observed in the post-capping period for coughing and wheezing. Adjusted analyses revealed increased PRs for coughing (PR = 1.92), shortness of breath (PR = 2.60), and wheezing (PR = 2.68) for any oil exposure. Increasing frequency of inhalation of oil was associated with increased likelihood of all three respiratory symptoms. A similar pattern was observed for contact with oil dispersants for coughing and shortness of breath. The combination of both oil and oil dispersants presented associations that were much greater in magnitude than oil alone for coughing (PR = 2.72), shortness of breath (PR = 4.65), and wheezing (PR = 5.06).

Conclusions: Results from the present study suggested strong relationships between oil and oil dispersant exposures and acute respiratory symptoms among disaster responders. Future prospective studies will be needed to confirm these findings.

1. Introduction

On April 20th, 2010, the Deepwater Horizon (DWH) drilling rig exploded, resulting in the release of approximately 200 million gallons of crude oil into the Gulf of Mexico over the next three months, making this the largest marine oil spill in U.S. history (United States Coast Guard, 2011). Additionally, nearly 2 million gallons of oil dispersants (mainly Corexit 9500 and 9527 A) were used in clean-up efforts. The United States Coast Guard (USCG) led the interagency response and coordinated clean-up activities, deploying over 8500 USCG personnel as responders.

A Health Hazard Evaluation Report of the DWH oil spill carried out by the Centers for Disease Control and Prevention (CDC) concluded that responders faced chemical exposures from crude oil and its components, dispersants used to break down the crude oil in the water, and in situ burning of crude oil (King and Gibbins, 2011). However, relatively little is understood about the human health effects from these exposures. Limited prior epidemiological studies have identified a number of acute physical, psychological, genotoxic, and endocrine effects in exposed populations (Aguilera et al., 2010; Laffon et al., 2016; Ordinioha and Sawyer, 2010). These observed effects may be due to the range of chemical agents encountered during oil spills (Ha et al., 2012).

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For example, crude oil typically contains volatile organic compounds (VOCs) such as benzene, toluene, ethylbenzene, and xylenes, polycyclic aromatic hydrocarbons (PAHs), and heavy metals (Liu et al., 2012). Inhalation of VOCs, in particular, is associated with respiratory symptoms such as respiratory tract irritation and bronchitis (Hulin et al., 2012). Further, as inhalation is the major route of exposure for many of these chemicals in the context of an oil spill, it is not surprising that prior epidemiological studies have shown an increased prevalence of respiratory symptoms in residents and clean-up workers immediately after exposure to an oil spill (Janjua et al., 2006; Meo et al., 2009; Meo et al., 2009; Peres et al., 2016), and that these effects may be prolonged after the spill (Rodriguez-Trigo et al., 2010; Zock et al., 2007, 2012).

Components of two primary dispersants used in the DWH response included propylene glycol and 2-butoxyethanol, which have been linked to respiratory irritation in both humans and animals (Agency for Toxic Substances and Disease Registry, 1997, 1998; Wieslander et al., 2001). After treatment with the dispersants Corexit 9500 and 9572 A alone or in combination with crude oil, studies in animal models have observed cell death and formation of reactive oxygen species in airway epithelial cells (Shi et al., 2013; Wang et al., 2012) and observed breathing difficulty (Roberts et al., 2011). A study recently published from the GuLF STUDY cohort (Kwok et al., 2017) found that potential exposure to either of these dispersants was significantly associated with respiratory symptoms (e.g., cough, wheeze, tightness of chest, and shortness of breath). (McGowan et al., 2017) In another recent study, Liu et al. reported that Corexit 9527 A appeared to act synergistically with crude oil in altering gene expression in human airway epithelial cells in vitro (Liu et al., 2016).

Though previous epidemiological studies have characterized respiratory health symptoms after oil spills, important gaps in our knowledge remain. Most of these previous studies have relied on proxies of exposure to crude oil, such as whether or not an individual participated in the clean-up, their duration of clean-up work, or proximity to the oil spill (Aguilera et al., 2010; Laffon et al., 2016; Ordinioha and Sawyer, 2010). Also, these studies were limited in sample size, and were unable to identify vulnerable subgroups through stratification of relevant factors. Additionally, few studies have examined the impact of use of personal protective equipment (PPE) on respiratory effects among oil spill clean-up workers (Carrasco et al., 2006; Gwack et al., 2012; Lee et al., 2009; Sim et al., 2010; Suarez et al., 2005; Zock et al., 2007), which could provide valuable guidance on reducing risk among these disaster workers.

Considering the paucity of data on crude oil, oil dispersants in general, use of PPE in responders and their association with respiratory health symptoms, along with the increasing number of oil spills in recent decades (Aguilera et al., 2010), the present study is positioned to fill important gaps in knowledge. Using a cross-sectional design, this study aims to examine the association between specific exposures encountered during oil spill clean-up work (crude oil/oily water and oil dispersants) and acute respiratory symptoms.

2. Methods

2.1. Study population

The current cross-sectional study was based on data from the DWH Oil Spill Responder Coast Guard cohort, which has been previously described (Rusiecki et al., 2017). Briefly, 8696 USCG responders who worked at least one day on the DWH oil spill response were identified via USCG administrative databases. Among these responders, 4855 (55.8%) completed an exit survey that queried information related to their deployment (timing, duration, missions), relevant exposures (crude oil, oil dispersants, exhaust fumes), health symptoms, PPE use, and lifestyle factors. All responders who completed this survey were included in the current analysis. This study was approved by the Institutional Review Boards of the Uniformed Services University, The United States Coast Guard, and The University of North Carolina, Chapel Hill.

2.2. Exposure assessment

Responders reported the deployment dates and duration of their DWH oil spill response in the exit survey. Frequency of exposure to crude oil/oily water was assessed via a 5 point Likert scale for each of four specific routes of exposure: inhalation, direct skin contact, ingestion, and submersion (e.g., “How often were you exposed to crude oil/oily water via inhalation/direct skin contact/ingestion/submersion?”). The present analyses on exposure to crude oil/oily water focused on inhalation exposure, though the other routes of exposure were considered in constructing a general exposure to crude oil variable. Frequency of exposure to oil dispersants was assessed via a 5 point Likert scale based on the question: “How often did you personally handle, apply, or come in contact with oil dispersants?” For both crude oil exposure and oil dispersant exposure, the five levels were: "all of the time," "most of the time," "sometimes," "rarely, and "never."

2.3. Assessment of acute respiratory symptoms

The acute respiratory symptoms assessed in the exit survey- coughing, shortness of breath, spitting up of blood, and wheezing - were reported by participants on a three-point scale: “Most of the time,” “Sometimes,” and “Never.” The current study focused on coughing, shortness of breath, and wheezing; spitting up of blood was dropped from analyses because it was reported by a low number of responders (n = 11).

3. Statistical analyses

Cross-sectional analyses of the exit survey exposure and health data were carried out in order to investigate the association between oil spill clean-up exposures of interest and acute respiratory symptoms. Responders with multiple deployments (n = 292) represented a small proportion of the cross-sectional study; therefore, analyses were limited to individuals’ first deployment only.

The effect of deployment length on respiratory health symptoms was evaluated. Deployment length was categorized into a three-level variable: less than or equal to 30 days, more than 30 days and less than or equal to 60 days, and more than 60 days. Because the oil well was capped on July 15, 2010 and exposure to fresh oil and other cleanup-related stressors likely changed after this date, timing of response (April 20th, 2010 - July 15th, 2010 vs. after July 15th, 2010) was examined jointly with duration of response in relation to respiratory health symptoms; thus models were stratified by period of response in relation to the capping of the well. Responders were classified as being deployed pre- or post-capping of the well according to the start date of their deployment. The post-capping period was truncated on September 30th, 2010 to exclude respiratory symptoms that might have been due to seasonal respiratory infections.

For exposure to crude oil/oily water exposure via inhalation and contact with oil dispersant exposures, a three-level variable was created: none, low, or high. The three-level categorical variables (none, low, high) for inhalation of crude oil exposure and oil dispersant were generated by combining “Rarely” and “Sometimes” into a “Low” category and “Most of the Time” and “All of the Time” into a “High” category. Finally, a general crude oil/oily water exposure variable, regardless of exposure route, was created as an ever/never variable, where indication of any exposure to oil via inhalation, direct skin contact, submersion, or ingestion was identified as “ever” exposed to oil. Respiratory health effects were analyzed by combining “Sometimes” and “Most of the Time” into an “Ever” category.

To avoid overestimation of effects due to non-rarity of the outcomes (Barros and Hirakata, 2003), adjusted log binomial regression was used