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ORIGINAL ARTICLE

Acute Health Effects Among Military Personnel Participating in the Cleanup of the *Hebei Spirit* Oil Spill, 2007, in Taean County, Korea

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Abstract
Objectives: This study was conducted to investigate acute health effects and its related factors among military personnel participating in the cleanup of the 2007 *Hebei Spirit* oil spill accident in Taean county, Korea.
Methods: We collected data on acute symptoms during the cleanup and their predictors using a self-administered questionnaire to 2624 military personnel. Self-reported symptoms included six neurologic symptoms, five respiratory symptoms, two dermatologic symptoms, three ophthalmic symptoms, and three general symptoms. Independent variables were demographic factors (gender, age, education level, and rank), health behavioral factors (smoking history and usage of the personal protective equipment such as masks and gloves), and occupational history such as where and for how long individuals participated in cleanup.
Results: The duration of work days was significantly associated with 17 acute symptoms except for itchiness and red skin. Working in Taean county also increased the risk of most acute symptoms except headache and back pain. In regard to personal protective equipment, wearing masks was mainly related to the development of respiratory symptoms such as sore throat and wearing other protective equipment was related to the development of sore throat, back pain, headache, and cough. Military personnel younger than 25 years reported 4.66 times more hot flushing and 5.39 times more itchiness than those older than 25 years.
Conclusion: It should be emphasized that for early-stage cleanup the number of workers should be minimized, sufficient personal protective equipment with approved quality for blocking noxious gas should be supplied, and systematic health care for the workers should be provided. Health effects could be diminished by providing adequate education regarding the appropriate use of

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protective equipment, especially to nonprofessionals such as residents and volunteers. To make disaster response expeditious, a national and regional preparedness plans and a professional response team for emergency environmental assessment and emergency action should be established beforehand to make prompt decisions.

1. Introduction

The Republic of Korea is a maritime country surrounded by sea on three sides; the western coast of the Korean peninsula is an important route for international exchange, which has increased greatly in recent years. The risk of various kinds of marine accidents, especially major accidents, is also growing as cargo ships are getting bigger and faster. As Korea is not an oil producer and import of crude oil has been steadily increased with economic growth, the traffic of gigantic oil tankers near Korean peninsula is also increasing due to the geopolitical situation of Korea, which limits land transport of oil. After a collision of oil tankers, oil spill leads to a fast and wide spread of oil by rapid ocean currents. On December 7, 2007, the Hong Kong-registered oil tanker, the *Hebei Spirit*, was rammed by a crane-carrying barge of Samsung Heavy Industries tugboats. As a result, about 10,900 tons of oil spilled into sea, which contaminated 1052 km of coast and 2000 ha of beach in Taean county, Korea [1].

The oil spilled from the *Hebei Spirit* was reported to contain volatile organic compounds (VOCs) such as benzene, toluene, ethylbenzene, xylene (BTEX), polycystic aromatic hydrocarbons (PAHs), and heavy metals [2]. VOCs in crude oil are easily volatilized to air and absorbed into the human body through the respiratory tract, inducing irritation in respiratory system or affecting central and peripheral nervous system, while PAHs are absorbed through the respiratory tract and skin, inducing headache, nausea, and dermatitis [3]. Some components of crude oil such as benzene have been identified as carcinogenic or probably carcinogenic to humans by the International Agency for Research on Cancer (IARC) [4]. Several studies on health effects of large-scale oil spills showed development of various physical and mental symptoms in volunteers and cleanup response teams [5−7].

From the day of the accident up to July 4, 2008, the total number of participants for land cleanup was 2,122,296, and included 556,323 residents, 1,226,730 volunteers, and 152,695 military personnel [2]. In the initial stage of cleanup, several health problems were posed because most participants were not able to wear appropriate personal protective equipment such as gowns, gloves, masks, and goggles and, even worse, children were allowed to participate in the cleanup [8]. Various physical symptoms such as headache and nausea were identified through a survey of the residents and workers by the Korea Centers for Disease Control and Prevention 5 days after the disaster [9]. Military personnel were deployed in the area for cleanup activities from December 8, 2007, the next day of the disaster, and concerns have been raised about their acute health effects. The purpose of the present study was to assess physical symptoms of military personnel participated in the oil spill cleanup and the factors related to them.

2. Materials and Methods

2.1. Participants

This study was performed to evaluate the effects of hazardous materials existing in oil on the health of 3198 military personnel participating in the cleanup for the *Hebei Spirit* oil spill from January 4 to February 19, 2008, using structured self-assessment questionnaires. The study population was 2624, excluding 574 nonrespondents or nonparticipants. The survey was conducted after explaining the purpose of this study and obtaining informed consent.

2.2. Investigation

Acute symptoms were surveyed systematically in previous studies [4,6]. Acute patients were defined as those who developed symptoms after participating in the cleanup, excluding those who had a previous history of similar symptoms. Symptoms were categorized as follows: neurologic symptoms such as headache, dizziness, nausea, fatigue, insomnia, and hot flushing; respiratory symptoms such as sore throat, dry mouth, runny nose, cough, and sputum; dermatologic symptoms such as itchiness and red skin; ophthalmic symptoms such as sore eyes, red eyes, and watery eyes; and general symptoms such as general ache, back pain, and febrile sense.

Factors affecting the development of acute symptoms were also surveyed. The factors included demographic factors such as gender, age, education, and rank; behavioral factors such as smoking history; personal protection such as use of masks and other equipment; and working history such as where and for how long individuals participated in the cleanup. The level of personal protective equipment usage was classified as ‘well equipped’ and ‘not well equipped’, and the place of cleanup was divided into ‘coastal region of Taean county’ and ‘other places’.

2.3. Statistical analysis

The Chi-square test and test for linearity were applied to assess the differences of self-reported rates of acute symptoms by sociodemographic characteristics, behavioral factors, level of personal protective equipment usage, and working history of cleanup. Factors with $p < 0.1$ or biological plausibility were selected for logistic regression to calculate odds ratios (ORs) for acute symptoms.

3. Results

3.1. Univariate analysis

Distribution of self-reported acute symptoms by contributing factors is shown in Table 1. As the work days of cleanup became longer, acute symptoms became significantly more prevalent, except for red skin. The military personnel who worked in Taean county had more symptoms than those who worked in other areas, except for itchiness. The younger group (aged under 25 years) had fewer symptoms except for red skin ($p = 0.3$). Officers had more symptoms than enlisted soldiers for cough ($p = 0.02$), sputum ($p < 0.01$), and general ache ($p = 0.04$). The individuals who had educational attainment of 12 years or longer had a significantly higher prevalence of itchiness ($p = 0.03$). Smokers had a higher prevalence of insomnia ($p = 0.01$), dry mouth ($p < 0.01$), cough ($p = 0.02$), back pain ($p = 0.04$), and febrile sense ($p = 0.05$). Headache ($p < 0.01$), dizziness ($p < 0.01$), nausea ($p < 0.01$), hot flushing ($p < 0.01$), cough ($p < 0.01$), sputum ($p < 0.01$), and itchiness ($p < 0.01$) were more prevalent in those who had worn masks well for personal protection. Headache ($p < 0.01$), sore throat ($p < 0.01$), and back pain ($p = 0.02$) were more prevalent in those who had worn personal protective equipment other than masks well.

3.2. Logistic regression analysis

The ORs and 95% confidence intervals (CIs) of contributing factors calculated for 19 self-reported acute symptoms are shown in Table 2. The duration of work days was significantly associated with 17 acute symptoms out of 19 symptoms in five categories. Working in Taean county also increased the risk of most acute symptoms, except for headache and back pain. In regard to personal protective equipment, wearing masks was mainly related to the development of respiratory symptoms such as sore throat (OR 2.06, 95% CI 1.64−2.59) and wearing other protective equipment was related to the development of sore throat, back pain, headache, and cough. Military personnel younger than 25 years reported 4.66 times more hot flushing and 5.39 time more itchiness than those older than 25 years. Enlisted soldiers tended to report 1.37 times more general ache than officers. Educational attainment was not significantly associated with acute symptoms. Current smokers had higher risks of fever, insomnia, dry mouth, back pain, and cough.

4. Discussion

This study was performed to assess acute health effects in military personnel who participated in the cleanup of the *Hebei Spirit* oil spill.

The present study showed that acute health effect was associated with where and how long they worked for cleanup and how well they wore personal protective equipment. The health effects of the *Sea Empress* oil spill were reported to be correlated with headache, nausea, eye irritation, and itchiness after adjusting for age, gender, anxiety score, smoking history, and health belief [7], and to be also significantly related to toxic symptoms such as headache, eye irritation, and sore throat due to physical exposure to crude oil [10]. Morita et al [6] reported a significant association between physical symptoms such as back pain, leg pain, headache, eye pain, and watery eye and contributing factors such as duration of cleanup and direct exposure history. A survey performed 1 month after the *Erika* oil spill around Brittany in France showed relationships between symptoms such as back pain, dermatitis, and headache and the duration of cleanup among the 3669 workers and volunteers [11]. Zock et al [12] indicated positive relationships between the prevalence of respiratory symptoms and amount and duration of work for cleanup in a study performed in 9050 representative fishermen 14−27 months after the *Prestige* oil spill. In this study, the respiratory symptoms were found to persist over a period of time; Janjua et al [5] presented a negative association between the distance from the place of oil spill and irritative symptoms on the skin, in the throat and eyes, and headache by comparing the residents who lived in the contaminated area and 2 and 20 km away from the area. Lee et al [9] found that residents in highly contaminated areas suffered from a significantly high prevalence of acute health effects such as headache, nausea, dizziness, fatigue, hot flushing, insomnia, diarrhea, sore throat, cough, rhinorrhea, dyspnea, sputum, dry mouth, itchiness, red skin, eye pain, general ache, back pain, and febrile sense compared to those in less contaminated areas [9]. Results of the present study were consistent with the results of these studies.

The level of exposure to oil may depend on personal behavior and environmental factors such as ocean currents and wind [13]. However, the present study categorized exposure levels according to their work areas: inside or outside of Taean county. For precise exposure measurements, environmental or human samples should be collected; however, it is difficult to obtain samples within hours or days after sudden disasters such as a marine oil spill, considering the

Table 1. Distribution of reported acute symptoms by socioecomic, health behavior, and cleanup work-related factors

Contributing factors	*N*	Neurological system						Respiratory system					Dermatologic system		Ophthalmic system			General symptoms		
		HA (%)	DZ (%)	NA (%)	FA (%)	IN (%)	HF (%)	ST (%)	DM (%)	RN (%)	CO (%)	SP (%)	IT (%)	RS (%)	SE (%)	RE (%)	WE (%)	GA (%)	BP (%)	FE (%)
Cleanup work days		$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p = 0.01$	$p = 0.07$	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$
1–7	747	26.1	19.9	14.9	13.4	5.0	4.6	4.8	4.3	10.6	6.4	5.9	5.4	3.7	5.9	2.9	1.7	4.8	7.1	1.7
8–14	268	20.5	13.8	11.9	11.6	6.7	4.9	6.3	3.7	12.7	13.1	13.1	6.3	3.0	3.7	0.7	3.0	8.6	7.5	6.0
15–21	598	29.9	21.7	14.2	12.5	6.7	9.5	7.9	6.2	12.9	9.9	9.4	5.9	3.5	5.4	2.7	4.5	7.5	10.5	6.2
>21	1,011	41.0	32.3	25.4	26.3	14.1	18.4	12.2	8.1	24.0	14.4	15.5	9.0	5.6	12.1	6.8	6.1	13.0	20.5	6.7
Cleanup work areas		$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p = 0.01$	$p = 0.05$	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p = 0.02$
Outside Taean county	534	10.9	10.3	8.4	6.9	4.3	4.7	3.2	3.2	8.2	6.2	8.2	5.1	2.2	2.2	0.7	1.9	4.5	4.5	3.2
Inside Taean county	2,090	37.6	28.1	21.1	20.8	10.3	12.7	9.9	6.9	18.6	12.2	11.9	7.5	4.9	9.4	5.0	4.8	10.1	15.3	5.6
Wearing masks well		$p < 0.01$	$p < 0.01$	$p < 0.01$	$p = 0.05$	$p = 0.16$	$p < 0.01$	$p = 0.06$	$p = 0.09$	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p = 0.13$	$p = 0.27$	$p = 0.75$	$p = 0.08$	$p = 0.17$	$p = 0.29$	$p = 0.08$
Yes	1,194	26.6	21.5	15.9	16.4	8.2	9.3	7.4	5.3	13.9	8.7	9.0	5.4	3.7	7.3	4.0	3.4	8.1	12.3	4.3
No	1,430	36.8	27.0	20.6	19.3	9.8	12.5	9.4	6.9	18.7	12.9	12.9	8.3	4.9	8.5	4.3	4.8	9.7	13.7	5.8
Wearing other PPEs well		$p < 0.01$	$p = 0.43$	$p = 0.89$	$p = 0.68$	$p = 0.22$	$p = 0.88$	$p < 0.01$	$p = 0.60$	$p = 0.33$	$p = 0.06$	$p = 0.28$	$p = 0.06$	$p = 0.50$	$p = 0.69$	$p = 0.63$	$p = 0.76$	$p = 0.99$	$p = 0.02$	$p = 0.93$
Yes	379	26.4	26.1	18.7	18.7	7.4	10.8	5.0	5.5	14.8	8.2	9.5	9.2	3.7	8.4	3.7	4.5	9.0	9.2	5.0
No	2,245	33.1	24.2	18.4	17.9	9.4	11.1	9.1	6.2	16.8	11.4	11.4	6.6	4.5	7.8	4.2	4.1	9.0	13.7	5.1
Age (y)		$p = 0.87$	$p = 0.11$	$p = 0.26$	$p = 0.97$	$p = 0.87$	$p = 0.08$	$p = 0.65$	$p = 0.98$	$p = 0.64$	$p = 0.83$	$p = 0.93$	$p = 0.46$	$p = 0.03$	$p = 0.54$	$p = 0.94$	$p = 0.57$	$p = 0.81$	$p = 0.87$	$p = 0.64$
<25	2,378	32.2	24.9	18.2	18.0	9.0	11.4	8.6	6.1	16.6	10.9	11.1	6.9	4.6	7.8	4.2	4.1	9.0	13.0	5.2
≥25	246	31.7	20.3	21.1	17.9	9.3	7.7	7.7	6.1	15.4	11.4	11.0	8.1	1.6	8.9	4.1	4.9	8.5	13.4	4.5
Military rank		$p = 0.74$	$p = 0.31$	$p = 0.08$	$p = 0.93$	$p = 0.16$	$p = 0.42$	$p = 0.26$	$p = 0.99$	$p = 0.74$	$p = 0.02$	$p < 0.01$	$p = 0.58$	$p = 0.24$	$p = 0.64$	$p = 0.16$	$p = 0.96$	$p = 0.04$	$p = 0.09$	$p = 0.37$
Officers	602	32.7	26.1	20.9	18.1	7.6	12.0	9.6	6.1	16.9	13.6	14.3	7.5	3.5	7.5	5.1	4.2	11.0	15.1	5.8
Enlisted soldiers	2,022	32.0	24.0	17.8	18.0	9.5	10.8	8.2	6.1	16.4	10.2	10.2	6.8	4.6	8.1	3.9	4.2	8.4	12.5	4.9
Educational attainment (y)		$p = 0.32$	$p = 0.53$	$p = 0.32$	$p = 0.48$	$p = 0.87$	$p = 0.80$	$p = 0.94$	$p = 0.31$	$p = 0.93$	$p = 0.12$	$p = 0.45$	$p = 0.03$	$p = 0.85$	$p = 0.18$	$p = 0.77$	$p = 0.18$	$p = 0.61$	$p = 0.90$	$p = 0.69$
≤12	384	34.4	25.8	20.3	19.3	8.9	10.7	8.6	7.3	16.7	13.3	12.2	9.6	4.2	9.6	4.4	5.5	9.6	13.3	4.7
>12	2,240	31.8	24.3	18.2	17.8	9.1	11.1	8.5	5.9	16.5	10.6	10.9	6.5	4.4	7.6	4.1	4.0	8.8	13.0	5.2
Cigarette smoking		$p = 0.36$	$p = 0.36$	$p = 0.32$	$p = 0.57$	$p = 0.01$	$p = 0.22$	$p = 0.41$	$p < 0.01$	$p = 0.11$	$p = 0.02$	$p = 0.11$	$p = 0.74$	$p = 0.59$	$p = 0.83$	$p = 0.40$	$p = 0.19$	$p = 0.70$	$p = 0.04$	$p = 0.05$
Nonsmoker	1,293	31.3	25.3	17.7	17.6	7.7	10.3	8.0	4.8	15.3	9.5	10.1	6.8	4.6	8.0	4.5	4.7	8.7	11.8	4.3
Smoker	1,331	33.0	23.7	19.2	18.4	10.4	11.8	8.9	7.4	17.7	12.4	12.1	7.1	4.1	7.8	3.8	3.7	9.2	14.4	5.9

BP = back pain; CO = cough; DM = dry mouth; DZ = dizziness; FA = fatigue; FE = febrile sense; GA = general ache; HA = headache; HF = hot flushing; IN = insomnia; IT = itchiness; NA = nausea; RE = red eyes; RN = runny nose; RS = red skin; SE = sore eyes; SP = sputum; ST = sore throat; WE = watery eyes.

Table 2. Odds ratios and 95% confidence intervals of self-reported symptoms in military personnel involved in cleanup work

	Contributing factors							
Symptoms	Cleanup work days	Cleanup work areas	Wearing mask well	Wearing other PPEs well	Age (y)	Military rank	Educational attainment	Current smoking
Neurological symptoms								
Headache	1.01 (1.00−1.02)	0.51 (0.41−0.64)	1.06 (0.91−1.24)	2.99 (2.41−3.72)	—	—	—	—
Dizziness	1.04 (1.03−1.05)	1.25 (1.05−1.49)	1.31 (1.12−1.54)	—	—	—	—	—
Nausea	1.04 (1.03−1.05)	1.57 (1.30−1.89)	1.39 (1.17−1.65)	—	—	1.12 (0.90−1.41)	—	—
Fatigue	1.04 (1.03−1.05)	1.54 (1.28−1.86)	1.58 (1.33−1.88)	—	—	—	—	—
Insomnia	1.06 (1.05−1.08)	2.73 (2.20−3.39)	—	—	—	—	—	1.70 (1.36−2.12)
Hot flushing	1.00 (0.99−1.02)	1.47 (1.14−1.90)	1.29 (1.03−1.60)	—	4.66 (3.69−5.89)	—	—	—
Respiratory symptoms								
Sore throat	1.03 (1.02−1.05)	1.35 (1.03−1.78)	2.06 (1.64−2.59)	3.55 (2.69−4.67)	—	—	—	—
Dry mouth	1.08 (1.06−1.09)	2.72 (2.11−3.50)	1.97 (1.52−2.55)	—	—	—	—	1.51 (1.16−1.96)
Runny nose	1.04 (1.03−1.05)	1.89 (1.56−2.29)	1.46 (1.22−1.74)	—	—	—	—	
Cough	1.03 (1.01−1.04)	1.34 (1.04−1.73)	1.50 (1.21−1.85)	2.91 (2.24−3.77)	—	1.05 (0.79−1.39)	1.12 (0.80−1.58)	1.25 (1.00−1.55)
Sputum	1.05 (1.04−1.06)	2.67 (2.16−3.29)	1.69 (1.33−2.15)	—	—	—	1.18 (0.81−1.72)	—
Dermatologic symptoms								
Itchiness	1.08 (1.07−1.10)	2.86 (2.25−3.64)	—	—	5.39 (3.99−7.30)	—	—	—
Red skin	1.07 (1.05−1.09)	1.69 (1.20−2.39)	—	—	—	—	—	—
Ocular symptoms								
Sore eyes	1.09 (1.08−1.10)	2.63 (2.12−3.27)	—	—	—	—	— —	—
Red eyes	1.13 (1.11−1.15)	3.55 (2.73−4.61)	—	—	—	—	— —	—
Watery eyes	1.10 (1.08−1.11)	3.54 (2.67−4.69)	2.46 (1.84−3.30)	—	—	—	— —	—
General symptoms								
General ache	1.07 (1.06−1.09)	2.82 (2.29−3.49)	—	—	—	1.37 (1.02−1.84)	—	—
Back pain	1.02 (1.01−1.03)	1.23 (0.97−1.56)	—	3.31 (2.60−4.22)	—	—	—	1.47 (1.20−1.80)
Fever	1.07 (1.05−1.09)	3.31 (2.53−4.34)	2.08 (1.58−2.74)	—	—	—	—	1.81 (1.36−2.40)

PPE = personal protective equipment.

volatility of VOCs and their short half-life inside the human body. Therefore, almost all previous studies have classified personal exposure levels by their places of work, with varying levels of contamination, and not by biological or toxicological tests [1].

Various components in crude oil spilled from marine accidents are known to have relatively low toxic effects because they are volatilized or vaporized and lost prior to reaching the coast [14]. Through modeling for estimating the effect of the *Hebei Spirit* oil spill, it was concluded that almost all VOCs in the oil were volatilized and moved along air currents [15]. The air contained various organic compounds that can act as endocrine disrupters and carcinogens, such as benzene and PAHs in high concentrations, and the oil spilled from the *Hebei Spirit* was relatively slowly vaporized [8]. Thus, a more active cleanup was required; the residents, volunteers, and military personnel who participated in the cleanup might have inhaled the air contaminated with the crude oil for a long period of time, which means that they were not free from their toxic effects [16].

The cleanup workers should be given appropriate protective equipment, especially gas masks with sufficient capacity to last for the first week [8]. Initial actions in response to the *Hebei Spirit* oil spill were blamed for inappropriate and insufficient protective equipment and lack of education regarding how to wear them [17]. Well-educated workers had used protective equipment in the correct manner and had a low prevalence of physical symptoms in case of the *Prestige* oil spill in Spain [18]. This finding is consistent with the result of the present study, where the workers who did not use masks properly had a higher prevalence of headache, dizziness, nausea, fatigue, sore throat, dry mouth, and rhinorrhea.

As the investigation of the present study was started 1 month after the event and, at first, the survey began with the workers of coastal area of Taean county where the level of contamination was relatively high, the recall bias might have affected their memories for acute symptoms. The design of the cross-sectional study could not be powerful enough to assess the effect of personal protective equipment. Information on the use of protective equipment during the high-exposure period, the first month after the event, was not obtained due to the late start of investigation, which is another limitation of the study and, thus, information only for the time of investigation was analyzed. The survey was conducted among military personnel only and the civilian volunteers were not compared to them in the study; therefore, the generalization of the results might be limited.

The present study demonstrated that various acute symptoms were associated with work in highly contaminated area, long duration of work, and inappropriate use of protective equipment. It should be emphasized to minimize the number of workers for early-stage cleanup, supply sufficient personal protective equipment with approved quality for blocking noxious gas, as well as provide systematic health care for the workers. Health effects could have been diminished by providing adequate education regarding appropriate use of protective equipment, especially in nonprofessionals such as residents and volunteers. To make disaster response expeditious, national and regional preparedness plans and a professional response team for emergency environmental assessment and emergency action should be established beforehand to make prompt decisions. Although the present study was limited to military personnel, it might be insufficient to support fully the long-term needs for control of health effects in the event of an oil spill. Problems regarding national actions for marine oil spills could be indicated and suggested improvements in the response system could be made based on the present study.

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