Chapter 30

REVIEW OF EPIDEMIOLOGICAL ANALYSES OF RESPIRATORY HEALTH OUTCOMES AFTER MILITARY DEPLOYMENT TO BURN PIT LOCATIONS WITH RESPECT TO FEASIBILITY AND DESIGN ISSUES HIGHLIGHTED BY THE INSTITUTE OF MEDICINE

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INTRODUCTION

Since military operations began in southwest Asia in 2001, the majority of US military personnel who have served during the last 12 years deployed at least once in support of Operation Enduring Freedom (OEF), Operation Iraqi Freedom (OIF), and/or Operation New Dawn.[1,2] On average, a deployment lasts 9 months. During that time, service members can be exposed to a wide range of environmental hazards that may impact their pulmonary health. Sources for such hazards include particulate matter (PM) indigenous to the desert environment; local industry-related pollutants; and exhaust from the engines of vehicles, machinery, and generators utilized by both military and civilians. It is also possible that deployed service members are at increased risk for both acute and chronic health effects as a result of exposures during deployment, including smoke emitted during the combustion of waste burned in open air burn pits.[3–5]

Prior to 2009, sophisticated solid-waste disposal means (Figure 30-1)—such as the use of incinerators and municipal combustors, containerized removal, or waste segregation for reuse/recycling—were unavailable at many OIF and OEF deployment locations. As a result, burn pits (Figure 30-2) were widely used as the main method for waste management. Defined as "an area, not containing … an incinerator or other equipment specifically designed … for burning of solid waste, designated for the purpose of disposing of solid waste by burning in the outdoor air at a location with more than 100 attached or assigned personnel and that is in place longer than 90 days."[6(p9)] Open air burn pits are uncontrolled by nature and are generally characterized by low-temperature burning and smoldering.[7]

The particulates and chemicals emitted by burn pits contribute to the total concentration of environmental pollutants that may have harmful health effects. Components of smoke emitted by burning waste that have the greatest potential to cause health effects include respirable PM of 10 μm in diameter or less (PM_{10}); fine PM of 2.5 μm in diameter or less ($PM_{2.5}$); lead; mercury; dioxins; furans; polycyclic aromatic hydrocarbons; volatile organic compounds (VOCs); and irritant gases.[7] The contribution of burning waste to the environmental concentrations of those contaminants may vary widely and is based on a number of factors; among these are the volume, moisture content, and composition of the materials being burned and meteorological conditions.[8,9]

Anecdotal reports of complaints by service members of respiratory symptoms have been attributed to exposure to burn pit smoke; and news outlets and members of Congress have expressed concern that exposure to burn pit smoke in certain deployed settings is causing adverse health effects.[3,4] In 2009, the Office of the Assistant Secretary of Defense for Health Affairs–Force Health Protection & Readiness tasked the Armed Forces Health Surveillance Center (AFHSC) to support a collaborative multiagency effort to comprehensively evaluate health effects potentially related to burn pit exposures at deployment locations by conducting epidemiological studies using readily available data.

Figure 30-1. Incinerators for solid waste disposal.

Figure 30-2. Burn pit.

HEALTH EFFECTS AMONG ACTIVE COMPONENT US SERVICE MEMBERS WHO DEPLOYED TO SELECT DEPLOYMENT LOCATIONS: 36 MONTHS' FOLLOW-UP

In response to Force Health Protection & Readiness' inquiry, AFHSC conducted a retrospective cohort study to:

- compare the incidence rates among deployers and nondeployers for respiratory diseases, circulatory disease, cardiovascular disease, ill-defined conditions, and sleep apnea;
- compare the responses on the postdeployment health assessment forms among the individuals deployed to one of several US Central Command (CENTCOM) locations; and
- compare the rates and proportions of medical encounters for respiratory outcomes while assigned to the various US CENTCOM locations.

For the purposes of this discussion, focus will be limited to the primary objective as it relates to respiratory health outcomes. The technical report can be viewed in its entirety, including results from the analyses conducted to address the other objectives and contributions from other collaborating agencies.[10]

Methods

Camp Cohorts

The Defense Manpower Data Center deployment roster was queried for all active duty service members deployed to Joint Base Balad (JBB) or Camp Taji in Iraq, and Camp Buehring or Camp Arifjan in Kuwait for more than 30 days between January 1, 2005 and June 30, 2007. Both Iraqi locations (JBB and Camp Taji) were selected because of the presence of burn pits at those deployment sites, whereas the two camps in Kuwait were selected for the similarity of their environmental characteristics to JBB and Camp Taji without having burn pits on location. During this time period, the population at JBB was as high as 25,000. The burn pit was estimated to be as large as 10 acres,[8,11] although not all areas were burning at any one time. Individuals were required to be at the specific camp at the end of their deployment so that any effects of the location resulting in medical encounters could be accurately captured immediately following the deployment. Personnel who spent time in more than one of the camps or who had multiple, noncontinuous segments in a specific camp during the deployment were excluded. Due to the small number of Marines (<2% of the total camp population) and no Navy personnel identified at these locations, camp cohorts were restricted to service members from the Army and the Air Force.

Comparison Groups

The Defense Medical Surveillance System personnel records were queried for all active duty service members with a history of being stationed in the Republic of Korea for more than 30 days, beginning any time during January 1, 2005 and June 30, 2007. This location was selected for a comparison population because of the meteorological phenomenon known as "yellow dust," which causes annual elevations in geogenic PM in the spring. Additionally, this overseas location was chosen because it requires certain health standards be met at the time of assignment, potentially making for a healthier population when compared with the general military population located in the continental United States (CONUS). The general CONUS military population includes individuals who are convalescing, who are in temporary nondeployable status for a variety of reasons, or who have permanent profiles and/or are in the process of separation from military service. Previously deployed personnel and those already selected for the Iraqi/Kuwait camp cohorts were excluded. A CONUS-based comparison group was also selected, which included all active duty service members who had never been deployed and stationed only in CONUS as of April 15, 2006. Personnel who appeared in any of the Iraqi/Kuwait camp cohorts or the Korea-based comparison group were excluded. Both comparison groups were restricted to service members from the Army and the Air Force because sailors and Marines were not represented in the camp cohorts.

Outcomes of Interest

All medical encounters at a military treatment facility—including both hospitalizations and ambulatory medical encounters—with an *International Classification of Diseases-Clinical Modification, 9th Revision* (ICD-9-CM), code in any diagnostic position indicating a disease of the respiratory system (460–519) during the 36-month follow-up period were captured. Any inpatient or outpatient visit was coded as

- an acute respiratory infection case was noted if ICD-9-CM codes 460–466 were indicated;
- a chronic obstructive pulmonary disease and an allied conditions case were noted if ICD-9-CM codes 490–492 or 494–496 were indicated;
- an asthma case was noted if ICD-9-CM code 493 was indicated; and
- signs, symptoms, and ill-defined conditions involving the respiratory system and other chest symptoms (SSIC [Standard Subject Identification Codes]–respiratory) were noted if ICD-9-CM code 786 was indicated.

Statistical Analysis

Incidence and 95% confidence intervals (CIs) for first diagnoses (number of incident diagnoses per 1,000 person-years) were calculated for each condition for each population. Incidence rate ratios (IRRs) and 95% CIs were calculated to compare the deployed populations to the CONUS-based population. IRRs were adjusted for covariates of importance—specifically age and grade (defined at start of follow-up)—as well as sex, race, and service using Poisson regression models. Negative binomial and zero-inflated negative binomial models were also explored, but provided similar estimates as the Poisson models and are therefore not reported. A service-stratified analysis and stratification by time in location were also conducted, but these results are not shown because they did not yield meaningfully different results from the overall analysis.

Results

Table 30-1 displays a comparison of the demographic and service-related covariates between the five cohorts. There were significant demographic differences in the deployed populations compared with the CONUS-based population. Specifically, the age makeup of the deployed population differed from the CONUS-based cohort, and the gender makeup of the deployed cohorts was different than the Korea and CONUS-based cohorts. JBB has a higher percentage of Air Force personnel, whereas Arifjan and Korea had a higher percentage of Army personnel. The Buehring and Taji cohorts were almost exclusively Army.

Crude unadjusted and adjusted IRRs varied depending on the camp and the outcome of interest (Table 30-2). For all outcomes, subjects from at least one of the camps or Korea had significantly lower incidence rates (*yellow shading*) compared with the CONUS-based cohort. The only outcome and camp with significantly higher unadjusted incidence rate (*green shading*) compared with the CONUS-based cohort was SSIC–respiratory among the Arifjan cohort (IRR = 1.10, 95% CI = 1.02, 1.19); however, this finding was not significant in the adjusted model. Specifically for JBB, adjusted incidence rates compared with the CONUS-based cohort were significantly lower for all outcomes except SSIC–respiratory, which showed no significant difference from the CONUS-based rate.

TABLE 30-1

DEMOGRAPHIC CHARACTERISTICS OF THE STUDY COHORTS: UP TO 36 MONTHS' FOLLOW-UP

	Balad		Taji		Arifjan		Buehring		Korea		CONUS	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Total	15,908	100.0	2,522	100.0	4,431	100.0	1,906	100.0	44,962	100.0	237,714	100.0
Age (yrs)												
<20	46	0.3	32	1.3	14	0.3	37	1.9	581	1.3	17,175	7.2
20–29	9,635	60.6	1,695	67.2	2,600	58.7	1,334	70.0	33,086	73.6	141,731	59.6
30–39	4,588	28.8	625	24.8	1,291	29.1	441	23.1	8,574	19.1	50,937	21.4
40+	1,639	10.3	170	6.7	526	11.9	94	4.9	2,721	6.1	27,871	11.7
Sex												
Female	2,478	15.6	317	12.6	554	12.5	205	10.8	9,094	20.2	55,720	23.4
Male	13,430	84.4	2,205	87.4	3,877	87.5	1,701	89.2	35,868	79.8	181,994	76.6
Race												
White	10,967	68.9	1,555	61.7	2,732	61.7	1,218	63.9	25,812	57.4	162,417	68.3
Black	2,388	15.0	581	23.0	971	21.9	345	18.1	10,022	22.3	37,583	15.8
Other	2,553	16.0	386	15.3	728	16.4	343	18.0	9,128	20.3	37,714	15.9
Rank												
E00–E04	6,354	39.9	1,256	49.8	1,707	38.5	988	51.8	26,828	59.7	126,564	53.2
E05–E09	7,092	44.6	1,004	39.8	2,028	45.8	693	36.4	13,546	30.1	62,466	26.3
O01–O10 (including warrant)	2,462	15.5	262	10.4	696	15.7	225	11.8	4,588	10.2	48,684	20.5
Service												
Army	3,989	25.1	2,522	100.0	2,873	64.8	1,904	99.9	32,553	72.4	100,726	42.4
Air Force	11,919	74.9	0	0.0	1,558	35.2	2	0.1	12,409	27.6	136,988	57.6

CONUS: continental United States

TABLE 30-2

INCIDENCE RATE RATIOS OF RESPIRATORY HEALTH OUTCOMES BY COHORT: UP TO 36 MONTHS' FOLLOW-UP

A. Incidence Rate Ratios for Respiratory Diseases (ICD-9-CM: 460–519)

				Unadjusted			Poisson Model		
	Person-years	Incidence	IR*1,000	IRR	95% Lower	95% Upper	IRR	95% Lower	95% Upper
Balad	18,132	6,477	357	0.89	0.87	0.91	0.91	0.88	0.93
Taji	2,866	900	314	0.78	0.73	0.84	0.86	0.81	0.92
Arifjan	4,950	1,847	373	0.93	0.89	0.97	1.00	0.96	1.05
Buehring	1,364	340	249	0.62	0.56	0.69	0.68	0.61	0.75
Korea	49,355	16,661	338	0.84	0.83	0.85	0.83	0.82	0.84
CONUS	272,903	109,563	401		REF			REF	

B. Incidence Rate Ratios of Acute Respiratory Infections (ICD-9-CM: 460–466)

				Unadjusted			Poisson Model		
	Person-years	Incidence	IR*1,000	IRR	95% Lower	95% Upper	IRR	95% Lower	95% Upper
Balad	20,446	4,859	238	0.87	0.84	0.89	0.90	0.88	0.93
Taji	3,128	686	219	0.80	0.74	0.86	0.90	0.83	0.97
Arifjan	5,698	1,333	234	0.85	0.81	0.90	0.95	0.90	1.00
Buehring	1,498	231	154	0.56	0.49	0.64	0.62	0.54	0.70
Korea	54,703	12,615	231	0.84	0.83	0.86	0.82	0.81	0.84
CONUS	311,221	85,382	274		REF			REF	

C. Incidence Rate Ratios of Chronic Obstructive Pulmonary Disease (ICD-9-CM: 490–492, 494–496)

				Unadjusted			Poisson Model		
	Person-years	Incidence	IR*1,000	IRR	95% Lower	95% Upper	IRR	95% Lower	95% Upper
Balad	25,923	564	22	0.84	0.77	0.92	0.91	0.84	0.99
Taji	3,802	93	24	0.95	0.77	1.16	0.83	0.68	1.02
Arifjan	7,174	186	26	1.00	0.87	1.16	0.98	0.85	1.13
Buehring	1,733	31	18	0.69	0.49	0.98	0.62	0.44	0.88
Korea	67,591	1,556	23	0.89	0.84	0.94	0.83	0.78	0.88
CONUS	415,659	10,749	26		REF			REF	

D. Incidence Rate Ratios of Asthma (ICD-9-CM: 493)

				Unadjusted			Poisson Model		
	Person-years	Incidence	IR*1,000	IRR	95% Lower	95% Upper	IRR	95% Lower	95% Upper
Balad	26,164	332	13	0.66	0.59	0.73	0.81	0.73	0.91
Taji	3,815	83	22	1.13	0.91	1.40	0.97	0.78	1.21
Arifjan	7,211	149	21	1.07	0.91	1.26	0.95	0.80	1.11
Buehring	1,720	32	19	0.96	0.68	1.36	0.76	0.53	1.07
Korea	67,638	1,386	20	1.06	1.00	1.12	0.91	0.86	0.96
CONUS	417,579	8,062	19		REF			REF	

(**Table 30-2** *continues*)

Table 30-2 *continued*

E. Incidence Rate Ratios of SSIC–Respiratory Symptoms and Other Chest Symptoms (ICD-9-CM: 786)

				Unadjusted			Poisson Model		
	Person-years	**Incidence**	**IR*1,000**	**IRR**	**95% Lower**	**95% Upper**	**IRR**	**95% Lower**	**95% Upper**
Balad	24,036	2,205	92	0.93	0.89	0.97	0.97	0.93	1.01
Taji	3,517	348	99	1.00	0.90	1.11	0.99	0.89	1.10
Arifjan	6,548	712	109	1.10	1.02	1.19	1.07	0.99	1.15
Buehring	1,617	129	80	0.81	0.68	0.96	0.79	0.67	0.94
Korea	32,919	5,931	94	0.95	0.93	0.98	0.91	0.89	0.94
CONUS	382,505	37,772	99		REF			REF	

CI: confidence interval; CONUS: continental United States; ICD-9-CM: *International Classification of Diseases-Clinical Modification, 9th Revision*; IR: incidence rate; IRR: incidence rate ratio; REF: reference value (equal to 1 for the CONUS groups); SSIC: Standard Subject Identification Codes
Notes: For all outcomes, subjects from at least one of the camps or Korea had significantly lower IRs (*yellow shading*) compared with the CONUS-based cohort. The only outcome and camp with significantly higher unadjusted IR (*green shading*) compared with the CONUS-based cohort was SSIC–respiratory among the Arifjan cohort (IRR = 1.10, 95% CI = 1.02, 1.19); however, this finding was not significant in the adjusted model.

Conclusions

The purpose of this analysis was to evaluate post-deployment healthcare encounters among personnel stationed at different in-theater locations in CENTCOM—two locations known to have burn pits and two locations without burn pits—and compare them with a similarly healthy group that may have been exposed to PM levels higher than in the United States (personnel assigned to Korea) and to a CONUS-based group. This study found no evidence that service members at burn pit locations are at an increased risk for the respiratory health outcomes examined up to 36 months' postdeployment. Although this analysis has its limitations, results generally show no impact of burn pit exposure up to 3 years later. Future analyses should focus on improving the quality of individual-level exposure data, including data from additional burn pit sites, and further investigate possible long-term health effects related to burn pit exposure.

LONG-TERM HEALTH CONSEQUENCES OF EXPOSURE TO BURN PITS IN IRAQ AND AFGHANISTAN

Scores of military personnel who served in support of the conflicts in Iraq and Afghanistan have returned home with reported health problems that they attribute to exposure to burn pit emissions during deployment. With concern also coming from families of veterans and Congress, as well as reports from media outlets and the publishing of scientific studies, the US Department of Veterans Affairs (VA) asked the Institute of Medicine (IOM) to form a committee tasked with making a determination of the long-term health effects associated with exposure to burn pits during OEF and OIF. Additionally, the committee was also asked to review feasibility and design issues of future epidemiological studies related to long-term health risks of veterans exposed to the burn pit at JBB. As a part of that effort, the report highlighting the AFHSC's analysis was reviewed, along with other peer-reviewed literature, government documents and data, and relevant reports on the subject. The IOM concluded, "service in Iraq or Afghanistan—that is, a broader consideration of air pollution than exposure only to burn pit emissions—might be associated with long-term health effects, particularly in highly exposed populations (such as those who worked at the burn pit) or susceptible populations (for example, those who have asthma), mainly because of the high ambient concentrations of PM from both natural and anthropogenic, including military, sources."[12(p7)]

In the assessment of the feasibility and design issues of an epidemiological study of veterans exposed to burn pit emissions, the committee concluded that the major challenges of such effort(s) are both exposure assessment and outcome ascertainment. The committee also identified the elements of a well-designed epidemiological study, including

- selection of a relevant study population of adequate size,
- comprehensive assessment of exposure,
- careful evaluation of health outcomes,
- reasonable methods for controlling confounding and minimizing bias,
- appropriate statistical analyses, and
- adequate follow-up time.

Study Design Elements

Study Population Selection

Identified within the IOM report as paramount to the success of an epidemiological study evaluating long-term health risks among veterans exposed to burn pit emissions is the proper selection of both exposed and comparison groups. Ideally, the exposed population is a representative sample of the population of interest, that is, military personnel deployed to locations with burn pits and comparison group(s) should be as similar to the exposed population as possible, with exception of the exposure of interest. Proper study population selection is done to avoid confounding, which occurs when there are differences in baseline characteristics between the groups, as well as bias, including bias related to the selection of exposed and unexposed groups.

In the original analysis conducted by AFHSC, it is not unexpected that one would see lower rates of respiratory health outcomes in the camp cohorts when compared with the CONUS-based population, which includes service members with health profiles considered ineligible for deployment. This issue of noncomparability is referred to as a "healthy warrior" or "healthy deployer" effect, a term used to "designate the selection bias from systematic differences in the health of military personnel who are deployed to a war zone and those who are not deployed due to the selective withholding of chronically ill soldiers from deployment."[13(p316)] To address the issue of noncompatibility, a cohort of military personnel stationed in Korea was selected for its greater degree of similarity in health status to the camp cohorts because service members with certain health problems cannot be supported by the limited healthcare resources found at many sites outside CONUS and therefore remain stationed at CONUS locations. More comparable yet would be a population of OEF/OIF-deployed service members who were located at base camps that utilized other methods of waste management; this would make the most appropriate comparison group for studying long-term health effects associated with exposure to burn pits, as indicated in the IOM report.

Exposure Assessment

According to the IOM report, obtaining accurate exposure profiles is also a key element in any successful environmental exposure-related epidemiological study. As the committee indicates, "exposure assessment characterizes the frequency, magnitude, and duration of exposure to an agent of concern in a population."[12] In an ideal study, exposure assessment would include ascertainment of quantitative exposure data for individual study subjects. Although personal monitors were never utilized and the burn pit at JBB is now closed (therefore, the opportunity to do so is lost), there are ways to estimate levels of exposure for study populations. Other information sources include, but are not limited to, exposure profiles provided on self-reported questionnaires, data from environmental sampling, modeling based on location in relation to the burn pit site, activities performed during deployment, and duration of exposure. Unfortunately, these methods of estimating exposure levels introduce measurement error (misclassification) and potentially bias measures of association between exposure and health outcomes. Differential misclassification would result from measurement errors in exposure that are related to health outcome or vice versa. Nondifferential misclassification describes measurement errors in exposure that are unrelated to health outcome or vice versa. In this case, one would suspect that any misclassification of exposure would occur irrespective of health outcome, resulting in nondifferential misclassification. In instances where self-reported information is used to formulate an exposure assessment, recall bias or the occurrence of exposed cohort study subjects (eg, recalling and reporting subsequent disease(s) more or less so than unexposed subjects) is possible. Recall bias would be an exception to nondifferential misclassification.

Evaluation of Health Outcomes

The IOM report also recognizes accurate ascertainment of health outcomes as just as important as accurate exposure assessment in conducting an epidemiological study examining the association between burn pit emission exposure and long-term health outcomes. As the committee points out, there are several sources of information from which to gather the health status of military personnel, including—but not limited to—electronic medical encounter records containing physician-coded diagnoses; disease registries containing health-related information for veterans and service members; and self-reported questionnaires containing items on postdeployment symptoms and disease. However, there are noted limitations associated with these sources of data. For example, coding errors in the classification of disease or the use of ICD-9-CM codes to describe chief complaints and current symptoms rather than the presence of disease by healthcare providers on electronic medical records would typically result in more cases of disease labeled than actually exist in the population. An illustration of the limitations presented by diagnostic coding is the increased use of bronchitis, not specified as acute or chronic (ICD-9-CM: 490). Although 10-year trends indicate that this code is being used more and more frequently, there is little understanding of what that diagnosis signifies in a clinical sense. Recall bias can occur on questionnaire responses if service members who were exposed to burn pit emissions are more (or less) likely to recall and report subsequent disease than their unexposed counterparts, or if service members with a respiratory diagnosis are more (or less) likely to accurately report past exposures relative to noncases. Use of data from disease registries can also present challenges, such as self-selection and free-text entries, as is the case with the

TABLE 30-3

INCIDENCE RATE RATIOS OF RESPIRATORY HEALTH OUTCOMES BY COHORT: UP TO 48 MONTHS' FOLLOW-UP

A. Incidence Rate Ratios for Respiratory Diseases (ICD-9-CM: 460–519)

				Unadjusted			Poisson Model		
	Person-years	Incidence	IR*1,000	IRR	95% Lower	95% Upper	IRR	95% Lower	95% Upper
Balad	19,425.05	6,798	349.96	0.90	0.88	0.92	0.92	0.90	0.94
Taji	3,029.93	931	307.27	0.79	0.74	0.84	0.86	0.81	0.92
Arifjan	5,287.34	1,916	362.38	0.93	0.89	0.98	1.01	0.96	1.05
Buehring	1,406.61	354	251.67	0.65	0.58	0.72	0.70	0.63	0.78
Korea	53,396.96	17,573	329.1	0.85	0.83	0.86	0.83	0.82	0.85
CONUS	294,779.87	114,579	388.69		REF			REF	

B. Incidence Rate Ratios of Acute Respiratory Infections (ICD-9-CM: 460–466)

				Unadjusted			Poisson Model		
	Person-years	Incidence	IR*1,000	IRR	95% Lower	95% Upper	IRR	95% Lower	95% Upper
Balad	22,180.31	5,173	233.22	0.88	0.85	0.90	0.91	0.89	0.94
Taji	3,336.14	717	214.92	0.81	0.75	0.87	0.90	0.84	0.97
Arifjan	6,182.94	1,399	226.27	0.85	0.81	0.90	0.95	0.90	1.00
Buehring	1,571.03	244	155.31	0.59	0.52	0.66	0.64	0.56	0.72
Korea	59,981.16	13,479	224.72	0.85	0.83	0.86	0.83	0.81	0.84
CONUS	340,952.18	90,461	265.32		REF			REF	

C. Incidence Rate Ratios of Chronic Obstructive Pulmonary Disease (ICD-9-CM: 490–492, 494–496)

				Unadjusted			Poisson Model		
	Person-years	Incidence	IR*1,000	IRR	95% Lower	95% Upper	IRR	95% Lower	95% Upper
Balad	29,254.33	640	21.88	0.85	0.79	0.92	0.91	0.84	0.99
Taji	4,165.45	103	24.73	0.96	0.79	1.17	0.86	0.71	1.05
Arifjan	8,051.75	211	26.21	1.02	0.89	1.17	1.00	0.87	1.15
Buehring	1,873.35	35	18.68	0.73	0.52	1.02	0.66	0.47	0.92
Korea	77,214.95	1,785	23.12	0.90	0.86	0.95	0.84	0.80	0.89
CONUS	477,289.63	12,231	25.63		REF			REF	

D. Incidence Rate Ratios of Asthma (ICD-9-CM: 493)

				Unadjusted			Poisson Model		
	Person-years	Incidence	IR*1,000	IRR	95% Lower	95% Upper	IRR	95% Lower	95% Upper
Balad	29,622.50	361	12.19	0.67	0.60	0.74	0.82	0.74	0.91
Taji	4,194.72	85	20.26	1.11	0.90	1.38	0.95	0.76	1.18
Arifjan	8,137.45	156	19.17	1.05	0.90	1.23	0.92	0.79	1.08
Buehring	1,855.05	33	17.79	0.98	0.69	1.38	0.76	0.54	1.07
Korea	77,477.95	1,504	19.41	1.07	1.01	1.13	0.91	0.86	0.97
CONUS	481,298.15	8,762	18.2		REF			REF	

(**Table 30-3** *continues*)

Table 30-3 *continued*

E. Incidence Rate Ratios of SSIC–Respiratory Symptoms and Other Chest Symptoms (ICD-9-CM: 786)

				Unadjusted			Poisson Model		
	Person-years	Incidence	IR*1,000	IRR	95% Lower	95% Upper	IRR	95% Lower	95% Upper
Balad	26,750.12	2,451	91.63	0.93	0.89	0.97	0.96	0.92	1.00
Taji	3,807.19	376	98.76	1.00	0.90	1.11	0.99	0.90	1.10
Arifjan	7,245.26	771	106.41	1.08	1.00	1.16	1.04	0.97	1.12
Buehring	1,723.88	139	80.63	0.82	0.69	0.97	0.80	0.68	0.94
Korea	70,650.63	6,781	95.98	0.97	0.95	1.00	0.93	0.91	0.96
CONUS	431,893.41	42,600	98.64		REF			REF	

CI: confidence interval; CONUS: continental United States; ICD-9-CM: *International Classification of Diseases-Clinical Modification, 9th Revision*; IR: incidence rate; IRR: incidence rate ratio; REF: reference value (equal to 1 for the CONUS groups); SSIC: Standard Subject Identification Codes
Notes: For all outcomes, subjects from at least one of the camps or Korea had significantly lower IRs (*yellow shading*) compared with the CONUS-based cohort. The only outcome and camp with significantly higher unadjusted IR (*green shading*) compared with the CONUS-based cohort was asthma among the Korea cohort (IRR = 1.07, 95% CI = 1.01, 1.13); however, this finding was significantly lower in the adjusted model.

VA registry established to track possible long-term health problems with respect to possible Agent Orange exposure.[14,15] Despite these known potential limitations, AFHSC is not only responsible for maintaining several surveillance databases that store health information for military personnel across the US Department of Defense (DoD), but also they have successfully linked these sources—that contain large amounts of data and have high enough statistical power to detect significant differences across cohorts—to accurately ascertain health outcome. The methodology used and the study findings have been published.[10]

Proposed Approaches to the Study of Health Outcomes From Exposure to Burn Pit Emissions

As part of the task of evaluating the feasibility and design issues of future epidemiological studies on the topic, the IOM committee outlined proposed approaches, organized in several tiers, to address research questions of interest.

Tier 1

The recommendation suggested in Tier 1 focused on the following question: Did proximity to burn pit operations at JBB increase the risk of adverse health outcomes? The proposed approach includes ordinal estimations of individual exposure assessments based on factors such as length of deployment, duties at JBB, distance and location of assigned barracks with respect to the burn pit, and wind dispersion patterns. Although length of deployment can be acquired from existing DoD data sources, there may not be a linear relationship between duration of deployment and burn pit emission exposure, given the truly unique deployment experience each individual service member has, as well as variability in burn pit emissions and meteorological conditions over time. Also readily available in DoD data sources are occupation codes; however, these codes may not reflect true job duties performed during deployment. For example, the burn pit at JBB had guard towers at its periphery to discourage local nationals from going into the pit to secure items still considered to be of value. Due to the nature of their duties, it might be anticipated that these individuals had the highest potential exposure; however, those assigned these duties are not identifiable with a single Military Occupation Series code. Although the importance of this recommendation is acknowledged, for the reasons previously stated, a valid exposure assessment tool would be needed to establish low, medium, or high exposures to burn pit emissions. For more information on exposure characterization and assessment tools, see Chapter 29 (Discussion Summary: Exposure Characterization—Questionnaires and Other Tools).

Tier 2

The recommendation suggested in Tier 2 seeks to address the following question: Did installation of incinerators at JBB reduce the incidence of disease or intermediate outcomes (eg, emphysema or rate of lung function decline)? This recommendation focuses on comparing long-term health outcomes of service members who were deployed to JBB while the burn pits were in full operation with those service members who were deployed to JBB after incinerators were installed. Such a comparison would include several different categories of exposure given the phased-approach taken to transition waste management at JBB from burn pits only to incinerators exclusively. Health risk assessments conducted during time periods of burn pit use (sampling performed in spring and fall 2007) compared with the use of incinerators (sampling performed March–May 2010) identified an increase in the number of samples detecting levels that indicated a potential for respiratory irritation. During open air burn pit operations, two chemicals (acrolein and hexachlorobutadiene) were detected over 1-year Military Exposure Guidelines (MEGs) in 1 of 41 samples in spring 2007, and acrolein detection was estimated to be over 1-year MEGs in 3 of 24 samples in fall 2007. After the burn pit was officially closed in October 2009 and incinerators were installed, a combination of chemicals (primarily acrolein) was detected over 1-year MEGs in 40 of 53 samples. These results may give the impression that there appears to have been a worsening in air quality after the installation of incinerators. However, the increased number and proportion of positive samples are thought to be from a change in laboratory methods used to analyze VOCs in the ambient air samples, from Toxic Organic (TO)-14 to TO-15 between 2007 and 2010 collection efforts. Specifically, the TO-15 method has increased extraction capability for VOCs over the TO-14 method. Consequently, comparing results for the sampling periods using the TO-14 method to the sampling periods using the TO-15 method is somewhat problematic. More work in this area would be needed to determine how these findings correlate with trends in health outcomes. Additional analyses to determine effectiveness of the intervention intended to reduce burn pit emissions exposure (based on rates of respiratory health outcomes) is certainly a worthy endeavor, especially given results from the health risk assessments that were conducted and considering that it was addressed neither by the AFHSC analyses nor any other known research efforts to date.

Tier 3

The research question proposed in Tier 3 is as follows: Did deployment at JBB during full burn pit operation increase risk of adverse health outcomes compared with deployment elsewhere in Iraq or Afghanistan or compared with no deployment? According to the committee, such a question could be addressed assessing exposure to JBB dichotomously. This yes/no exposure categorization broadly indicates exposure to the comprehensive environmental hazards found at JBB rather than serving as a marker for burn pit emission exposure solely. Health outcomes among those who were deployed to JBB while the burn pits were in operation could then be compared with health outcomes of military personnel deployed elsewhere. This proposed approach has been utilized in the past, as described in the assessments conducted by both AFHSC and the Naval Health Research Center (San Diego, CA) as part of the Millennium Cohort Study that were included in the 2010 published technical report *Epidemiological Studies of Health Outcomes Among Troops Deployed to Burn Pit Sites*.[10]

HEALTH EFFECTS AMONG ACTIVE COMPONENT US SERVICE MEMBERS WHO DEPLOYED TO SELECT DEPLOYMENT LOCATIONS: 48 MONTHS' FOLLOW-UP

In the summary of their original analysis, AFHSC acknowledged that future studies should be focused on further investigating possible long-term health effects related to burn pit exposure. The IOM committee also identified adequate follow-up time as a key element of a well-designed epidemiological study. In light of these statements, the first analysis conducted by AFHSC, which included up to 36 months of follow-up postdeployment, has since been updated to include up to 48 months of follow-up postdeployment.

Results

Crude unadjusted and adjusted IRRs varied depending on the camp and the outcome of interest (Table 30-3). For all outcomes, subjects from at least one of the camps or Korea had significantly lower incidence rates (*yellow shading*) compared with the CONUS-based cohort. The only outcome and camp with significantly higher unadjusted incidence rate (*green shading*), compared with the CONUS-based cohort, was asthma among the Korea cohort (IRR = 1.07, 95% CI = 1.01, 1.13); however, this finding was significantly lower in the adjusted model. When compared with the CONUS-based cohort, adjusted incidence rates

TABLE 30-4

MEDIAN AND MEAN FOLLOW-UP TIMES BY COHORT AND ANALYSIS (MONTHS)

	Up to 36 Months' Follow-up		Up to 48 Months' Follow-up	
	Median	**Mean**	**Median**	**Mean**
Balad	1.42	1.67	1.44	1.90
Taji	1.40	1.55	1.41	1.70
Arifjan	1.49	1.67	1.52	1.89
Buehring	0.51	0.93	0.51	1.00
Korea	1.34	1.54	1.41	1.77
CONUS	1.71	1.80	1.74	2.08

CONUS: continental United States

for JBB were significantly lower for all outcomes except SSIC–respiratory, which showed no significant difference from the CONUS-based rate. The median and mean follow-up times for both the original and updated analyses are provided in Table 30-4.

Conclusions

The purpose of this analysis was to increase the follow-up time of the original assessment of health effects among active component service members who deployed to select locations, from 36 months to 48 months. As in the original analysis, this extended analysis found no evidence that service members at burn pit locations are at an increased risk for the respiratory health outcomes examined up to 48 months postdeployment. Furthermore, the extended follow-up analysis showed the same pattern of findings as the original analysis for JBB compared with the CONUS-based cohort, with significantly lower adjusted incidence rates for all respiratory outcomes except SSIC–respiratory that was not significantly different from the CONUS-based rate. Results generally show no impact of burn pit exposure up to 4 years later.

SUMMARY

In addition to outlining proposed questions for future research, the IOM committee highlighted three elements on which to focus when conducting epidemiological studies investigating the association between burn pit emission exposure during deployment and long-term health outcomes:

1. proper study population selection,
2. accurate exposure assessment, and
3. precise ascertainment of health outcomes.

To ensure selection of the most appropriate study population, a cohort of military personnel stationed in Korea was included in these analyses. This was done to address the healthy warrior/healthy deployer effect, providing a group more comparable in health status to the camp cohorts than service members at CONUS locations, as indicated by results presented in Table 30-2 and Table 30-3. Studies conducted to date have typically used deployment to a location with a burn pit as a proxy for exposure to burn pit emissions in the absence of individual-level exposure data. Given the lack of exposure information on a service member-by-service member basis, Korea was also selected to serve as a comparison group due to the potential for exposure to higher PM levels (when compared with a CONUS reference group) as a result of the seasonal yellow dust phenomenon. Despite including a group that may have similar PM exposure to deployed cohorts in the analyses discussed, future efforts should emphasize improved quality of individual-level exposure data.

To improve on health outcome assessment, the original analysis conducted using up to 36 months of follow-up time was extended to include up to 48 months of follow-up. However, median times did not increase notably (Table 30-4), indicating loss to follow-up. Even the follow-up times in the updated analysis would not likely be sufficient time to develop the chronic respiratory health outcomes of interest, which is a limitation that has been noted in previous epidemiological work,[16] highlighting the need for and stressing the importance of a more seamless healthcare system between active duty service and veteran status for truly longitudinal evaluations. Thus, an Integrated Electronic Health Record is currently in development that will combine electronic health record systems of both departments, thus creating a single health record across all DoD and VA medical facilities.[17,18]

These findings should be balanced by the understanding that there are limitations to this study. First, data were not available on individual environmental exposures over time; therefore, all individuals at a location were assumed to have been equally exposed to the conditions of that location. Numerous factors, such as those mentioned by Smith et al,[16] including composition of materials being burned and prevailing wind conditions—as well as deployment duties (apart from or in addition to job classification) and specific duty locations—would have likely had an impact on individual environmental exposures within the camp; however, such data are not available. The bias introduced when such broad exposure definitions are used (exposure misclassification)[16] would weaken the strength of associations found between burn pit emissions exposure and postdeployment respiratory outcomes. Further complicating exposure assessment is the lack of data on where individuals were located prior to being at the camps of interest. If individuals did not spend their entire deployment at one of the specific camps, they may have been exposed to other environmental conditions while at different locations. Second, health outcomes were defined using administrative medical data, which likely resulted in false positives for a variety of reasons, including ICD-9-CM coding errors in the classification of disease and the use of diagnostic codes to describe chief complaints and current symptoms rather than actual disease.

Analyses of postdeployment healthcare encounters are impacted by the fact that all personnel following redeployment are required to have at least one healthcare encounter to complete postdeployment health assessment processing around the time of return, and another visit 3 to 6 months later to complete postdeployment health reassessment processing. This type of mandatory healthcare encounter is not counted as a condition, but may introduce an opportunity to identify a diagnosis. This situation may introduce a surveillance bias that can exaggerate effects observed in deployers when compared with nondeployers. Also, because healthcare during deployment is often limited, "catch up" on requirements such as well-woman examinations, immunizations, and other mandatory visits also occur postdeployment.

Despite efforts to choose cohorts that would be similar to each other, there were significant demographic differences between the study groups necessitating adjustment when comparing results. The question remains if there are unknown/unmeasured determinants of health status that vary between the comparison groups and that may therefore confound the results. Most notable of these would be smoking status, which has significant impacts on respiratory illness and has been shown to increase during deployment. A prospective evaluation performed by the Millennium Cohort Study team found greater percentages of smoking initiation in never-smokers, smoking resumption in past smokers, and increased smoking in current smokers among service members with a history of deployment when compared with nondeployers.[19] Another finding suggests that the prevalence of smoking was found to be 50% higher among deployed versus nondeployed service members.[20] Most recently, Szema et al[21] found that the difference in smoking between deployed and nondeployed military personnel was 16.1% and 3.3%, respectively. Unfortunately, the smoking status of service members is not routinely collected and recorded in any databases readily available to DoD researchers.

Although the results presented are not without limitations and assessment of the feasibility and design issues for epidemiological studies conducted by the IOM highlights areas where improvement is needed for future work, these analyses conducted by AFHSC met all major elements of a well-designed epidemiological study, when possible. Although this study found no evidence that service members at burn pit locations are at an increased risk for respiratory health outcomes on a population level, these findings do not rule out the possibility that certain individuals exposed to smoke from a burn pit may subsequently develop adverse respiratory health conditions. The good health of our active duty service members is needed not only for CENTCOM efforts, but also for every mission and likewise (eg, the well-being of our veterans after serving should be of primary importance). For these reasons, ongoing efforts should continue to focus on further investigating possible long-term health effects related to burn pit exposure, with particular attention aimed at improving the quality of individual-level exposure data in the future.

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