AIRBORNE HAZARDS RELATED TO DEPLOYMENT

Section II: Population Surveillance

A service member receiving a medical evaluation at a military treatment facility.

Photograph: Courtesy of the US Army Public Health Command (Aberdeen Proving Ground, Maryland).

Chapter 6

EPIDEMIOLOGY OF AIRBORNE HAZARDS IN THE DEPLOYED ENVIRONMENT

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INTRODUCTION

Monitoring, maintaining, and promoting the health of current and former US military personnel is a priority of the US Department of Defense (DoD) and the US Department of Veterans Affairs (VA).[1,2] Deployed personnel are exposed to a vast array of airborne hazards, and it is plausible that these deployment-associated airborne hazards affect postdeployment respiratory health.[3] Some military personnel have returned from deployment to southwest Asia (SWA) with persistent respiratory symptoms, and a subset is being diagnosed with chronic respiratory illnesses.[4–6] Epidemiological evaluations of potential deployment-associated environmental health risks can detect trends in adverse respiratory health conditions, aid in quantifying the burden of postdeployment respiratory disease, and identify risk factors for respiratory diseases. The DoD and VA are conducting evaluations of the relationship between deployment and incidence of postdeployment respiratory symptoms and specific chronic lung conditions. In addition, the DoD and VA are evaluating investigations being conducted in the broader community.

Studies of veterans have assessed two different groups: (1) patients at VA facilities seeking care for conditions that may be related to their military service, and (2) veterans with no known specific service-related health concerns. In a VA-conducted study of exposure concerns among nontreatment-seeking US military personnel,[7] self-reporting of environmental concerns immediately after deployment in support of Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF) was low (less than 12% change relative to predeployment exposure), and chart reviews conducted in a separate analysis reported an average of less than three exposure concerns per veteran of OIF/OEF.[8] However, neither of these investigations surveyed exposure to air pollutants, perhaps because air pollutants are practically ubiquitous.[9,10] There is reason to be concerned about air pollution-related health effects,[11–13] but the risk in the deployed military population is not well characterized. The known potential health effects of chronic exposure to particulate matter (PM) include chronic obstructive pulmonary disease (COPD), increases in lower respiratory symptoms, reduction in lung function, and reduction in life expectancy, primarily from cardiorespiratory-specific mortality. The effects of air pollution are population-specific, with most effects observed among the very young, the elderly, and those with underlying conditions that increase susceptibility to air pollution health effects.[12]

At the outset of both OIF and OEF, the DoD began conducting environmental sampling in the Central Command Area of Operations to characterize the deployment environment.[14] The most widespread air pollutant documented by ambient air sampling was PM.[10] Particulate levels varied by location, although average levels were uniformly high across SWA relative to levels typically encountered in the United States. The sources of PM air pollution in SWA are many, including blowing sand and dust, combustion of fossil fuels from vehicles and industry, and fires. Although levels of PM on average are higher in SWA, compared with the US, the composition of PM in samples from US military bases in SWA is generally similar in terms of chemical and mineralogical constituents to samples from the US, the Sahara, and China.[10,15] PM samples typically contain mixtures of silicate minerals, carbonates, oxides, sulfates, and salts in various proportions. Differences lie in the relative proportions of these minerals and chemical components in different soils. In comparison with the Sahara, China, and the US, the SWA samples had lower proportions of silicon dioxide and higher proportions of calcium oxide and magnesium oxide.[10,15] Extremely high PM levels in the region have been attributed to short-term dust events exacerbated by dirt roads, agricultural activities, and disturbance of the desert surface by motorized vehicles.

Exposure to smoke from burning waste has been of particular concern to OIF- and OEF-deployed military personnel.[3,16,17] Disposing of solid waste in large, open "burn pit" operations has been common practice at US camps in Iraq and Afghanistan. A burn pit is defined as an area, not containing a commercially manufactured incinerator or other equipment specifically designed and manufactured 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.[18]

Burn pit emissions likely vary because of heterogeneity in the trash stream and combustion characteristics. Individuals' activity patterns and meteorological conditions additionally influence exposures to burn pit emissions.

Several studies either describing deployment-related environmental conditions or seeking to establish an association of exposure to this environment and the subsequent health outcomes among troops have been completed or are under way.

The purpose of this chapter is to summarize the epidemiological evaluations being conducted by the US Army Public Health Command (USAPHC), the Armed Forces Health Surveillance Center (AFHSC), the Department of VA Post-Deployment Health Epidemiology Program, as well as by other US government and nongovernment research centers. Trends in select health conditions—primarily chronic respiratory diseases—and their relationship to deployment experiences are presented, followed by a discussion of the issues and implications of the findings of these studies, particularly in the context of a recent Institute of Medicine report on the long-term health consequences of exposure to burn pits in Iraq and Afghanistan.[3]

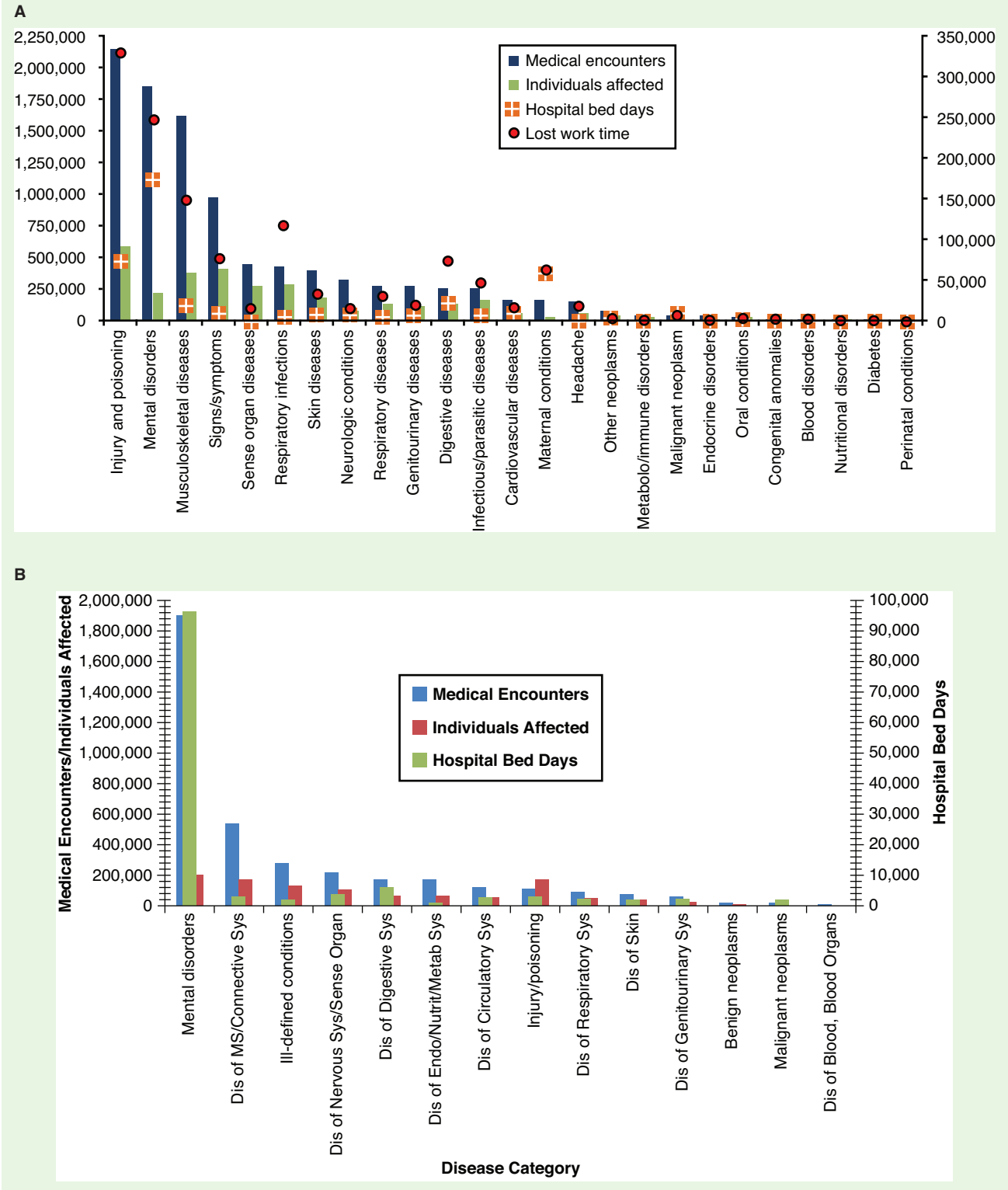

Figure 6-1. (**A**) Department of Defense Burden of Disease Data, 2011. (**B**) Veterans Affairs Burden of Disease Data, 2011. Dis: disease; Endo: endocrine; Metab: metabolism; MS: musculoskeletal; Nutrit: nutrition; Sys: system

BURDEN OF DISEASE AND SURVEILLANCE TRENDS

Figure 6-1 presents the 2011 burden of disease data for the DoD and VA, respectively. Respiratory disease ranks far below the major drivers of healthcare utilization; for example, in the DoD, the number of medical encounters for respiratory diseases (250,000) was seven times less than medical encounters for injuries (more than 2 million). Among VA beneficiaries, the roughly 100,000 medical encounters for diseases of the respiratory system are dwarfed by almost 1.9 million medical encounters for mental disorders. However, respiratory diseases account for a substantial portion of medical encounters, ranking ninth in terms of healthcare utilization among both the DoD and VA populations.

In 2012, the AFHSC conducted a comparison of ambulatory medical encounters and hospitalizations among active duty US military personnel during prewar (January 1998–August 2001) and wartime periods (October 2001–June 2012).[19] The rate of medical encounters for respiratory diseases increased from 149.7 encounters per 1,000 person-years prewar to 173.2 encounters per 1,000 person-years during the war period (incidence rate ratio = 1.16; 95% CI [confidence interval]: 1.08–1.24). However, hospitalizations for respiratory diseases decreased from 1.4 hospitalizations per 1,000 person-years to one hospitalization per 1,000 person-years (incidence rate ratio = 0.71; 95% CI: 0.28–1.73) over the same period.

Between 2000 and 2011, rates of medical encounters for asthma (ICD [International Classification of Diseases]-9 diagnosis code 493) and COPD (ICD-9 diagnosis code 491 and ICD-9 diagnosis code 492) decreased in all branches of the military (Figure 6-2). However, medical encounter rates for respiratory symptoms (ICD-9 diagnosis code 786) and bronchitis not specified as acute or chronic (ICD-9 diagnosis code 490) have increased (see Figure 6-2). Medical encounter rates for respiratory symptoms,

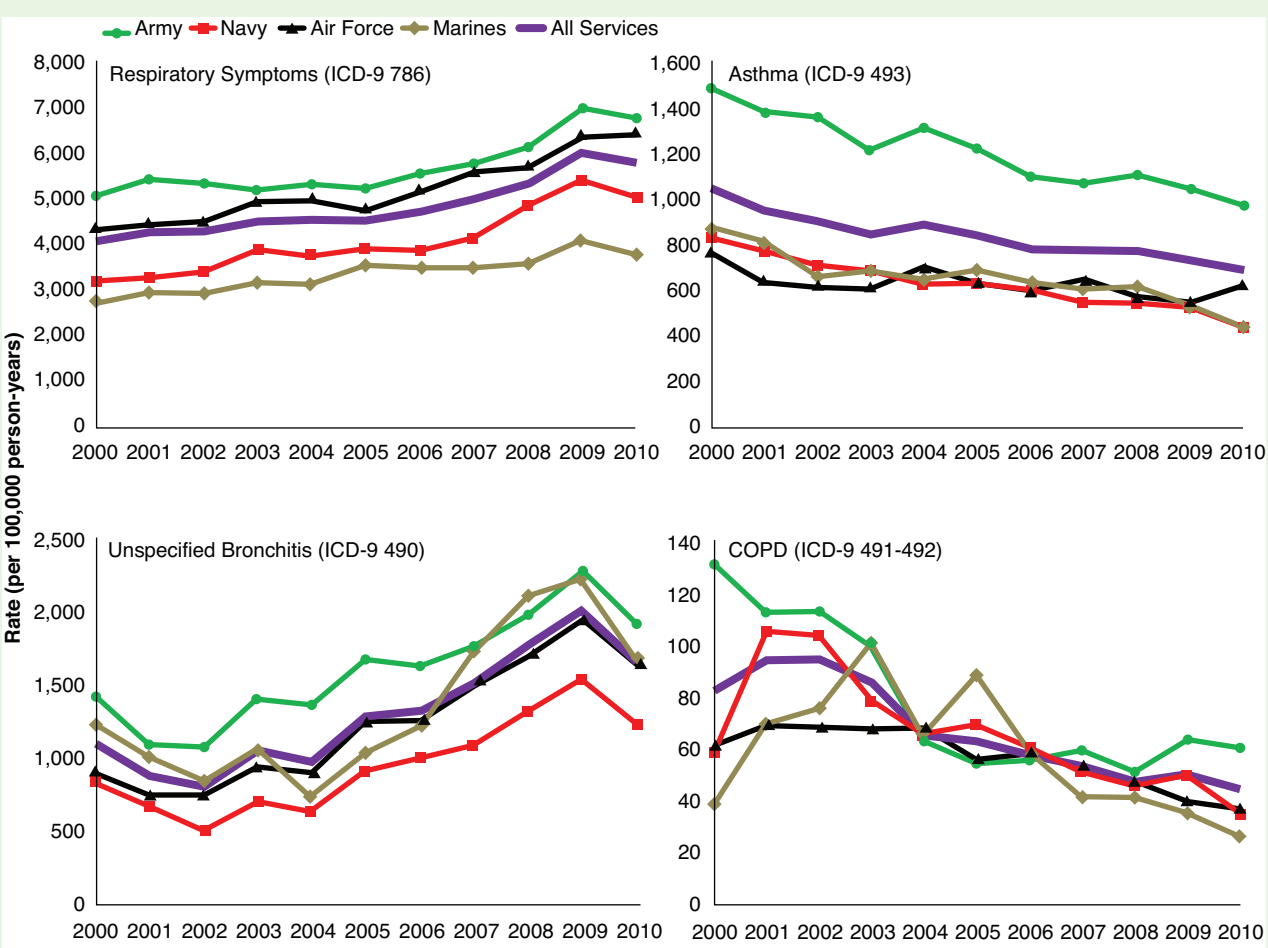

Figure 6-2. Rates of respiratory symptoms and diseases among the services, 2000–2010.
COPD: chronic obstructive pulmonary disease; ICD: *International Classification of Diseases*

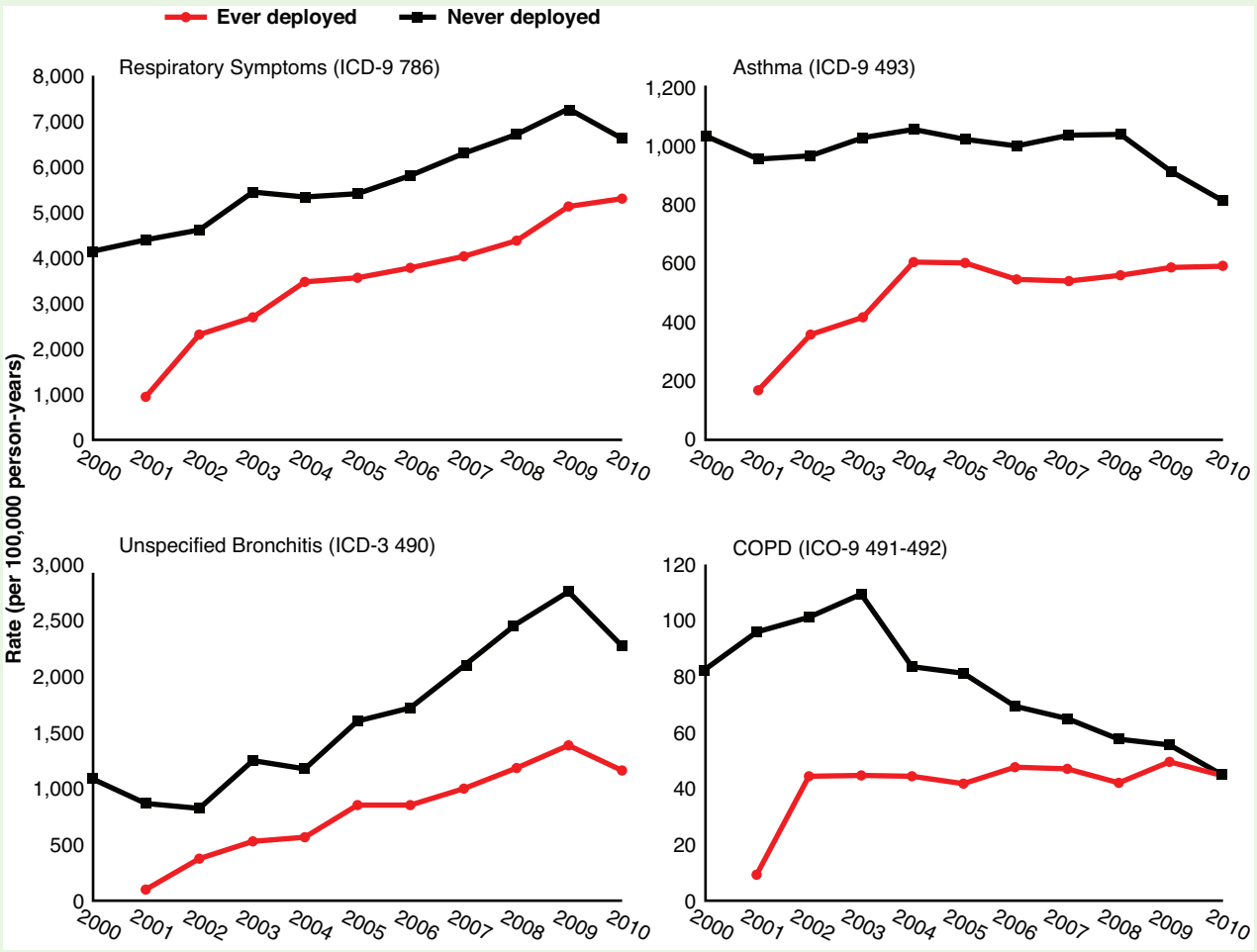

Figure 6-3. Rates of respiratory symptoms and diseases among ever-deployed and never-deployed service members, 2000–2010.
COPD: chronic obstructive pulmonary disease; ICD: *International Classification of Diseases*

asthma, and bronchitis not specified as acute or chronic were uniformly lower among personnel who had deployed at least once (*ever-deployers*), compared with personnel who had no history of deployment (*never-deployers*), although annual incidence trends generally followed the same pattern among ever-deployers as never-deployers (Figure 6-3). These data provide evidence that nondeployed (ie, "unexposed") personnel may not be exchangeable[20] with deployed (ie, "exposed") personnel with respect to baseline health status. Therefore, caution is urged regarding the use of nondeployed personnel as a comparison group for estimating relative and absolute risks in epidemiological studies. Medical encounter rates for chronic bronchitis and emphysema are a possible exception; rates for these conditions appear to be decreasing after 2003, whereas they are stable or slightly increasing among ever-deployed personnel. In 2010, the most recent year for which data were analyzed, COPD medical encounter rates among never- and ever-deployers were approximately the same. Among the VA beneficiary population, rates of asthma, bronchitis, COPD, and chronic bronchitis have been relatively stable over a similar time period (Figure 6-4).

SUMMARY OF EPIDEMIOLOGICAL STUDIES

A summary of the investigations summarized below can be found in Table 6-1. In 2004, Sanders et al[21] initiated a Naval Medical Research Center survey designed to assess the impact of illness and injury during OIF and OEF deployments. The investigators administered a questionnaire to consenting military personnel leaving Iraq or Afghanistan at the end of their deployments. Among 15,459 respondents, 69% self-reported having a respiratory illness during their

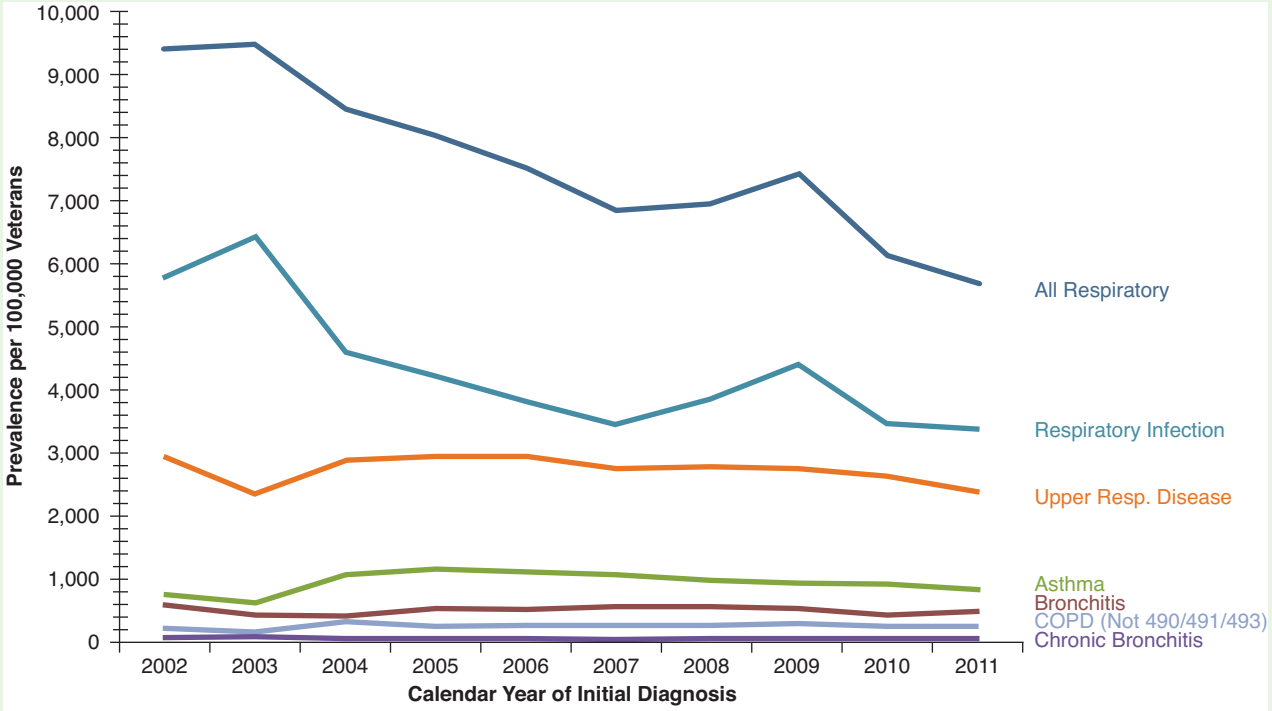

Figure 6-4. Rates of respiratory diseases among the Veterans Affairs beneficiary population, 2002–2011.
COPD: chronic obstructive pulmonary disease; Resp: respiratory

deployment. Twenty-two percent of those surveyed reported having an allergy attack, and almost 4% reported having an asthma attack. Greater than one-third (39%) of all respondents reported smoking at least one-half pack of cigarettes per day. Among the self-identifying smokers, 48% either began smoking or restarted smoking during their deployment. The cross-sectional design of the study captured prevalent rather than incident disease, and the survey design was dependent on accurate and reliable self-reporting of conditions. Those who agreed to participate in the study may not have been representative of the larger pool of redeploying military personnel, which would serve to limit generalizability of the prevalence figures.

In 2007, Roop et al[22] reported on a survey designed to assess the prevalence and severity of respiratory symptoms among asthmatics and nonasthmatic active duty Army personnel and DoD contractors returning from OIF and OEF deployments.[22] The prevalence of respiratory symptoms (wheezing, cough, sputum production, and chest pain/tightness) and allergy symptoms following deployment were statistically significantly increased relative to predeployment. Thirty-one percent of the survey respondents were former or current smokers.

In 2009, investigators at the Naval Health Research Center (NHRC) conducted a prospective study designed to assess the relationship between deployment to Iraq and Afghanistan and newly reported respiratory symptoms and respiratory conditions. This study by Smith et al[4] found no difference in the rate of chronic bronchitis, emphysema, or asthma when comparing deployers to nondeployers. However, they observed statistically significant increases in the odds of newly reported respiratory symptoms among formerly deployed Army and Marine Corps personnel compared with nondeployers. Strengths of the study include its prospective design, measurement and adjustment for demographic characteristics and behaviors (including smoking status), and inclusion of personnel from all branches and components of the military in the cohort. The study utilized data garnered from self-administered questionnaire surveys; it lacked the precise information necessary to evaluate associations between specific exposures and pathologies. Its follow-up period was relatively short (2.7 years on average), which precluded elucidation of associations between deployment and diseases characterized by long latency periods.

In 2010, a collaboration of researchers at AFHSC, NHRC, and USAPHC produced a report (*Epidemiological Studies of Health Outcomes Among Troops Deployed to Burn Pit Sites*) in response to a tasking from the Office of the Assistant Secretary of Defense for Health Affairs to conduct expedient evaluations of health effects potentially related to exposures to burn pits at deployment locations.[23] The AFHSC conducted a retrospective evaluation of postdeployment

TABLE 6-1

SUMMARY OF EPIDEMIOLOGICAL REPORTS OF DEPLOYMENT-ASSOCIATED RESPIRATORY HEALTH OF US MILITARY PERSONNEL AND VETERANS

Reference	Study Design	Summary of Findings
Abraham and Baird *J Occup Environ Med* 2012;54:733–739	Case crossover	No evidence of an association between in-theater PM2.5 and acute cardiorespiratory medical encounters
Abraham et al *J Occup Environ Med* 2012;54:740–745	Retrospective cohort	Increase in postdeployment respiratory symptoms and medical encounters for obstructive pulmonary diseases, relative to predeployment rates, in the absence of an association with cumulative deployment duration or total number of deployments
Szema et al *J Occup Environ Med* 2011;53:961–965	Retrospective cohort	Rates of respiratory symptoms leading to a diagnosis requiring spirometry are high among veterans formerly deployed to SWA
Szema et al *Allergy Asthma Proc* 2010;31:67–71	Retrospective cohort	Deployment to Iraq was associated with a higher prevalence of asthma compared with nondeployed soldiers (6.6% vs 4.3%)
AFHSC DoD report, 2010	Retrospective cohort	Deployment to bases in SWA is associated with signs, symptoms, and ill-defined conditions, but is not associated with encounters for respiratory diseases, respiratory infections, circulatory system diseases, and respiratory symptoms; findings are not specific to burn pit locations
NHRC DoD report, 2010	Prospective cohort	Deployment to a base camp with a burn pit was not associated with increased risk of respiratory outcomes, chronic multisymptom illness, lupus, rheumatoid arthritis, birth defects, or preterm birth
Smith et al *Am J Epidemiol* 2009;170:1433–1442	Prospective cohort	Deployment was associated with respiratory symptoms in the Army and Marine Corps, but not associated with respiratory disease diagnoses
Smith et al *Am J Epidemiol* 2009;170:1433–1442	Cross-sectional survey	Prevalence of respiratory symptoms increased during deployment, compared with predeployment for both asthmatics and nonasthmatics
Sanders et al *Am J Trop Med Hyg* 2005;73:713–719	Cross-sectional survey	Prevalence of respiratory illness among deployed personnel is high (69%); prevalence of respiratory infections doubled from precombat to combat phases

AFHSC: Armed Forces Health Surveillance Center; DoD: US Department of Defense; NHRC: Naval Health Research Center; PM: particulate matter; SWA: southwest Asia

respiratory diseases, circulatory diseases, cardiovascular diseases, and sleep apnea in response to the tasking. The AFHSC found no increase in the rates of medical encounters for these conditions among active duty US Army and Air Force personnel formerly deployed to US military bases with burn pit operations in Iraq, compared with personnel stationed in the continental US without a history of OIF/OEF deployment (see 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). Similar or significantly lower incidence rates were also observed among personnel deployed to locations in Kuwait that operated without burn pits relative to the nondeployed reference group. The AFHSC used deployment to a base camp as a proxy for ambient environmental exposures, including burn pit emissions. The design did not include each deployed individual's actual environmental exposures. This approach allows the potential for errors in the assigning of exposure among the deployed study subjects (ie, differential exposure misclassification). It also precluded the ability to determine study-specific associations between many deployment-related exposures (environmental and otherwise) and postdeployment health status. In addition, the study lacked data on potential confounders and effect modifiers, the most important of which is smoking. Although these analyses did

control statistically for age and other demographic characteristics of the population, the negative findings may also have been because of the use of a never-deployed reference group that differed systematically from the exposed groups with respect to baseline health status. The health outcomes defined in the study were based on ICD-9–coded inpatient and outpatient medical encounters pulled from military medical records. It is possible that such medical encounters are imperfect proxies for incident disease, instead, for example, representing preexisting disease. It is also possible that individuals with incident disease either do not present, or have not yet presented, for medical care related to their condition, and therefore are not represented in the medical record. The study focused on health conditions among personnel presenting with respiratory complaints shortly after deployment; as a consequence of the limited follow-up time (a maximum of 3 years postdeployment), the study has almost no power to assess associations between military deployment and diseases of longer latency (eg, emphysema, chronic bronchitis, and lung cancer). Finally, the generalizability of the AFHSC results may also be limited, because they included only active duty components of the Army and Air Force.

In the same 2010 report, the NHRC assessed adverse birth outcomes, respiratory illnesses, chronic multisymptom illness, lupus, and rheumatoid arthritis in relationship to the deployment histories of participants in the Millennium Cohort Study (MCS). The NHRC studies included active duty, Reserve, and National Guard personnel of all services.[23] Overall, deployment to a base camp with a burn pit was not associated with increased risk of respiratory outcomes, chronic multisymptom illness, lupus, or rheumatoid arthritis. However, odds of newly reported lupus were elevated among cohort participants with a history of deployment to one of the locations with a burn pit (Joint Base Balad in Iraq). In the primary analysis, the potential burn pit emissions exposure was not associated with an increase in birth defects or preterm birth. However, the NHRC investigators did observe an increase in the odds of birth defects among a subset of infants whose fathers were exposed more than 280 days prior to the estimated date of conception. In contrast to the AFHSC evaluation, the NHRC study collected information on, and adjusted for, smoking status and physical activity among other demographic, behavioral, and military characteristics of the MCS participants. However, similar to the AFHSC study, the NHRC study used deployment to a military base camp location as a proxy for environmental exposures and is, therefore, similarly susceptible to bias caused by differential exposure misclassification and limited in its ability to resolve specific deployment-associated exposure effects. The NHRC analyses are also susceptible to confounding by unmeasured occupational and behavioral factors that are determinants of postdeployment health status. The health outcomes in the NHRC study are self-reported by MCS participants and may be subject to differential errors in reporting (ie, differential health outcome misclassification), although the NHRC researchers reported that previously conducted investigations of such bias indicate that the MCS participants provide reliable data with responses unaffected by their health status prior to enrollment.[24,25]

Two retrospective studies by a research group at the Veterans Administration Medical Center (VAMC) in Northport, New York, have investigated the relationship between deployment and respiratory health among veterans receiving care at the VAMC's OIF and OEF clinics, comparing them with veterans receiving care at the same medical center but who were not deployed in support of OIF or OEF. In the first study, Szema et al[26] found that 6.6% of veterans deployed to Iraq or Afghanistan had received an asthma diagnosis compared with 4.3% of veterans who were stationed in the United States. The study also reported a statistically significant age- and gender-adjusted estimated increase in the odds of asthma (88%), comparing OIF/OEF deployed veterans to their nondeployed counterparts. In the second study, Szema et al[27] conducted a medical record review of former active duty military personnel registered at the Northport VAMC to assess the relative frequency of respiratory symptoms indicating follow-up spirometric assessment among veterans formerly deployed in support of OIF or OEF compared with veterans who did not deploy to SWA. More than 14% of veterans with a history of OIF/OEF deployment were found to have respiratory symptoms and a follow-up spirometric evaluation compared with fewer than 2% among personnel without a history of OIF/OEF deployment. The inference from this finding is limited by the potential confounding bias; the prevalence of smoking was higher among the formerly deployed group of veterans (16.1%) compared with the nondeployed veterans (3.3%). Despite this observed difference, investigators did not adjust their findings for confounding by smoking status. The authors did not observe differences in clinical disease between veterans with and without a history of deployment, spirometric results were very similar between the two groups, and lung function following either bronchoprovocation or bronchodilation was not assessed. It is not clear from the published reports of either of these studies if attempts were made to exclude prevalent cases of respiratory disease. Neither of the studies evaluates specific environmental or other exposures, relying instead on history of OIF/OEF deployment as a nonspecific proxy for environmental and other exposures that may affect risk of respiratory conditions, similar to the AFHSC and NHRC studies discussed previously. Finally, the representativeness of the Northport VAMC patients with respect to the larger veteran population is not evaluated in these studies. Although the authors draw general conclusions from the results of these studies, their generalizability may be limited to veterans who have a baseline risk of respiratory disease similar to those veterans seen at the Northport VAMC.

In 2012, USAPHC investigators reported on a case-crossover study of ambient PM levels and cardiorespiratory conditions among US active duty military personnel deployed to 15 locations in SWA.[28] The study found no statistically significant associations between daily PM levels and daily rates of in-theater cardiovascular and respiratory-related medical encounters. Strengths of the study included restriction of confounding by design with respect to factors that do not exhibit day-to-day variability (eg, smoking) and the use of measured exposure levels. However, the assessment evaluated every-sixth-day ambient PM levels rather than personal exposures, allowing for the possibility of nondifferential exposure measurement error. The study was also limited in statistical power by its relatively small sample size (2,838 cases) and short duration (1 year). Finally, the study design limited the outcome assessment to potential acute effects of PM.

This same USAPHC group conducted a retrospective assessment examining the relationship between deployment history and postdeployment respiratory health among a random sample of active duty US military personnel formerly deployed in support of OIF or OEF.[5] They observed no statistically significant elevation in the frequency of medical encounters for obstructive pulmonary diseases (asthma, COPD, and allied conditions) among personnel with a history of multiple deployments relative to those with a single deployment. Cumulative duration of deployment was also not significantly associated with medical encounters for obstructive pulmonary diseases. However, they did observe an increase in the rate of medical encounters for respiratory symptoms and encounters for obstructive pulmonary diseases (predominantly asthma and bronchitis) in the postdeployment period relative to a 6-month period prior to deployment. The study shares many of the same limitations as the NHRC and AFHSC studies discussed previously; the authors did not assess specific exposures. The short follow-up period prevents the assessment of associations between deployment and diseases with longer latency. The investigators did collect and adjust for relevant demographic characteristics, but they did not adjust for smoking behaviors. The health outcomes were defined using ICD-9 medical encounter data and are imperfect proxies for incidence of disease. The authors did not assess the Reserve and Guard components of the military, which may limit the generalizability of the findings.

DISCUSSION

The epidemiological evidence to date is inconclusive regarding any definitive associations, or lack thereof, between deployment in support of US contingency operations in SWA (OIF, OEF, and Operation New Dawn) and respiratory health among deployed and formerly deployed military personnel. Findings from different scientific studies include the following:

- no evidence of an association between deployment and respiratory conditions;
- an association between specific lung disease and deployment;
- an association between deployment and increased respiratory symptoms, but not of specific, physician-diagnosed disease; and
- increased frequency of asthma in the VA healthcare system, which is a driver of overall healthcare utilization.

As discussed elsewhere in this chapter, case series have also described particular conditions generating hypotheses regarding a link between environmental exposures encountered while deployed and postdeployment respiratory health[1] (see Chapter 14, Value of Lung Biopsy in Workup of Symptomatic Individuals). All of these studies have methodological limitations that constrain the strength of the drawn conclusions, including limitations in the study methods and regarding exposure, health outcome, and confounder assessment.

No single study can provide or present a definitive answer. The significance of a study's contribution to the overall body of evidence should be based on a consideration of both its strengths and limitations. Findings should be balanced against limitations regarding study design, including

- adequacy of comparison groups,
- exposure assumptions,
- how outcomes are assessed,
- latency periods,
- confounding and other epidemiological biases, and
- low statistical power.

Arriving at an evidence-based conclusion regarding associations between deployment-associated environmental exposures and long-term respiratory health of military personnel is challenging for several reasons. This is a relatively new area of scientific investigation. As discussed, a small but growing number of assessments evaluating associations between military deployment to SWA and subsequent health status of military personnel and veterans have been published in the peer-reviewed scientific literature. The current body of evidence includes multiple studies putatively assessing the same relationship, but with inconsistent findings. Multiple, well-conducted studies with consistent results are

typically needed to support a strong conclusion regarding an exposure–disease relationship. Current work is ongoing to fulfill this need.

The epidemiological studies assessing health effects of inhalational hazards in deployed environments are susceptible to the sources of bias common to all epidemiological studies, including selection bias, wherein the baseline health status of comparison groups is not necessarily comparable. Information bias is from errors in the assignment of exposure and health outcome status, and confounding.

Bias from confounding by factors that are both predictive of deployment exposures and determinants of respiratory health is a particular weakness of the investigations reviewed previously. Most notably, smoking behaviors, which increase with deployment[21] and are among the strongest known behavioral determinants of respiratory health, are often not known to researchers. Even when smoking data were available, they were not consistently used to adjust for confounding. In addition, changes in smoking behaviors that occur during deployment (eg, initiation of smoking and increasing frequency among current smokers) may be intermediate determinants of postdeployment health conditions.

Errors in the characterization of exposures present a substantial limitation of the current literature. Although conceptually one may be interested in exposure to specific pollutants and their sources, most of the studies reviewed herein use OIF/OEF deployment or deployment to a specific location as a proxy for environmental exposures. Thus, operationally, the indicators or surrogates of the exposures of interest are assessed. The primary impact of this limitation is twofold. These methods almost certainly misclassify the inhalational exposures whose impact is the aim of the assessment. Such measurement error can result in biased associations and corresponding estimates of uncertainty. In general, these biases attenuate the estimates of associations. In addition, it is plausible that changes in behaviors, occupational exposures, or other nonenvironmental exposures coincide with deployment. In addition to smoking, other potential determinants of observed respiratory disease risk include massing of personnel in confined spaces, changes in chronic stress levels, combat-related exposures, and bias from changes in medical attention-seeking behaviors that are both associated with deployment and predictive of subsequent frequency of respiratory and other medical encounters and conditions. With the exception of the case-crossover study by Abraham and Baird,[28] that was limited to assessments of acute associations, none of the studies reviewed previously can discriminate between the impacts of myriad environmental exposures or between the effects of environmental exposures and the impacts of coincidental, nonenvironmental exposures. For those studies that identify an association between deployment and subsequent health conditions, one can only speculate as to the underlying exposure or exposures that are responsible for the observation. As a result of this limitation, there has been no epidemiological evidence to date that specifically implicates any specific exposure (eg, burn pit emissions) as a necessary or sufficient cause of postdeployment chronic respiratory symptoms or disease incidence.

Health outcomes assessed in these studies are also likely to be measured with error. Again, the potential consequence of such errors is an attenuation of observed associations if the errors are not related to exposure status.

A further practical limitation of many of these studies is heterogeneity in the definition of the outcomes. For example, case definitions of COPD or asthma have not been consistently applied from study to study. Although there are, at times, legitimate reasons for such heterogeneity, researchers should endeavor to decrease these differences across various research groups to the extent possible.

The relatively short length of follow-up common to the cohort studies reviewed precludes statistically powerful assessments of associations between deployment-associated exposures and diseases of long latency, such as emphysema, chronic bronchitis, and many cancers. Because military personnel commonly separate from the service within a few years of deployment, assessments that leverage DoD medical data will remain limited in this respect. The VA, in contrast, is in a unique position to establish long-term follow-up of former service members. The representativeness of the VA beneficiary population with respect to the larger population of formerly OIF-/OEF-/Operation New Dawn-deployed US military personnel is imperfect, however, which may impact the generalizability of future assessments set in this population.

Reports of individual cases may be newsworthy, but can also easily distort or distract from the interpretation of available scientific evidence. Such cases are often compelling and deserving of the public's attention and may serve as clues to the scientific community for their hypothesis-generating potential. However, individual case reports alone do not provide strong scientific evidence of an association between deployment-related exposures and the condition. Further studies are needed to explore any potential relationships.

Findings from the Institute of Medicine report *Long-Term Health Consequences of Exposure to Burn Pits in Iraq and Afghanistan*[3] indicate that service in Iraq or Afghanistan—ie, 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 or susceptible populations that are mainly from the high ambient concentrations of PM from both natural and anthropogenic (including military) sources. Indeed, the epidemiological evidence has not identified specific risk factors for postdeployment chronic respiratory health conditions. In the few studies that have examined specific exposures, no associations were observed. More often, epidemiological studies have used nonspecific indicators of exposure. Such studies, by design, cannot inform questions about specific exposures. The DoD and VA are working to expand the evidence base using more refined methods.

SUMMARY

The epidemiological evidence to date does not support definitive conclusions regarding associations, or an absence thereof, between deployment-associated environmental exposures and chronic respiratory conditions among service members and veterans. Epidemiological methods are being implemented to improve understanding of the potential impacts of deployment on the health of those who have been deployed. It should be noted that no matter how refined the methodology, no epidemiological study can prove that a causal association does not or cannot exist. Rather, an epidemiological study merely provides one data point: that an association of a given magnitude was or was not observed. This piece of evidence must then be taken together with evidence from all other sources, put in the context of mission requirements, and used to inform military policy and public health practice. Completely avoiding exposure to airborne hazards in the deployed environment is not feasible. However, steps can be taken to maximize postdeployment respiratory health. As suggested by the National Research Council Committee that reviewed the DoD's report titled *Enhanced Particulate Matter Surveillance Program*,[15,29] exposures should be minimized if and when possible; emissions sources (eg, burn pits and generator banks) can be located downwind from areas of personnel locations, and burning of waste, if necessary, should be conducted when meteorological conditions support dispersion of emissions. Perhaps, most importantly, antismoking and smoking cessation programs should focus on deploying and deployed personnel. Finally, the health and research community serving military personnel and veterans would be well served to extend its research focus beyond burn pits when evaluating sources, exposures, and health effects. Both the DoD and VA will no doubt continue to prioritize the identification and care of current and former military personnel who fall ill. Future research and public health efforts should focus on minimizing the known behavioral determinants of respiratory health conditions (eg, smoking among deployed personnel), mitigate exposures to environmental hazards and their sources, and identify individual-level determinants of warfighter and veteran susceptibility to, and resiliency against, austere and inhospitable environmental conditions.

REFERENCES

1. Morris MJ, Zacher LL, Jackson DA. Investigating the respiratory health of deployed military personnel. *Mil Med.* 2011;176:1157–1161.

2. Baird C. The basis for and uses of environmental sampling to assess health risk in deployed settings. *Mil Med.* 2011;176(suppl 7):84–90.

3. Institute of Medicine of the National Academies. *Long-Term Health Consequences of Exposure to Burn Pits in Iraq and Afghanistan*. Washington, DC: The National Academies Press; 2011:1–9, 31–44, 117–129.

4. Smith B, Wong CA, Smith TC, et al. Newly reported respiratory symptoms and conditions among military personnel deployed to Iraq and Afghanistan: a prospective population-based study. *Am J Epidemiol*. 2009;170:1433–1442.

5. Abraham JH, DeBakey SF, Reid L, et al. Does deployment to Iraq and Afghanistan affect respiratory health of US military personnel? *J Occup Environ Med*. 2012;54:740–745.

6. Rose C, Abraham J, Harkins D, et al. Overview and recommendations for medical screening and diagnostic evaluation for postdeployment lung disease in returning US warfighters. *J Occup Environ Med.* 2012;54:746–751.

7. Quigley KS, McAndrew LM, Almeida L, et al. Prevalence of environmental and other military exposure concerns in Operation Enduring Freedom and Operation Iraqi Freedom veterans. *J Occup Environ Med.* 2012;54:659–664.

8. Helmer DA, Rossignol M, Blatt M, et al. Health and exposure concerns of veterans deployed to Iraq and Afghanistan. *J Occup Environ Med*. 2007;49:475–480.

9. Brown KW, Bouhamra W, Lamoureux DP, et al. Characterization of particulate matter for three sites in Kuwait. *J Air Waste Manag Assoc.* 2008;58:994–1003.

10. Engelbrecht JP, McDonald EV, Gillies JA, et al. Characterizing mineral dusts and other aerosols from the Middle East—part 1: ambient sampling. *Inhal Toxicol.* 2009;21:297–326.

11. Davidson CI, Phalen RF, Solomon PA. Airborne particulate matter and human health: a review. *Aerosol Sci Technol.* 2005;39:737–749.

12. Pope CA 3rd. Epidemiology of fine particulate air pollution and human health: biologic mechanisms and who's at risk? *Environ Health Perspect.* 2000;108(suppl 4):713–723.

13. Pope CA 3rd, Dockery DW. Health effects of fine particulate air pollution: lines that connect. *J Air Waste Manag Assoc.* 2006;56:709–742.

14. Weese CB, Abraham JH. Potential health implications associated with particulate matter exposure in southwest Asia. *Inhal Toxicol*. 2009;21:291–296.

15. Engelbrecht JP, McDonald EV, Gillies JA, Gertler AW. Final report. *Department of Defense Enhanced Particulate Matter Surveillance Program (EPMSP)*. Reno, NV: Desert Research Institute; 2008. Contract W9124R-05-C-0135/SUBCLIN 000101-ACRN-AB.

16. Smith B, Wong CA, Boyko EJ, et al. The effects of exposure to documented open-air burn pits on respiratory health among deployers of the Millennium Cohort Study. *J Occup Environ Med.* 2012;54:708–716.

17. Taylor G, Rush V, Deck A, Vietas JA. *Screening Health Risk Assessment: Burn Pit Exposures Balad Air Base, Iraq and Addendum Report.* Aberdeen Proving Ground, MD: Army Center for Health Promotion and Preventive Medicine; 2008. Technical Report 47-MA-08PV-08.

18. US Department of Defense. *Use of Open-Air Burn Pits in Contingency Operations.* Washington, DC: DoD; 2011. DoD Instruction 4715.19.

19. Armed Forces Health Surveillance Center. Costs of war: excess health care burdens during the wars in Afghanistan and Iraq (relative to the health care experience pre-war). *MSMR.* 2012;19:2–10.

20. Greenland S, Robins JM. Identifiability, exchangeability, and epidemiological confounding. *Int J Epidemiol.* 1986;15:413–419.

21. Sanders JW, Putnam SD, Frankart C, et al. Impact of illness and non-combat injury during Operations Iraqi Freedom and Enduring Freedom (Afghanistan). *Am J Trop Med Hyg.* 2005;73:713–719.

22. Roop SA, Niven AS, Calvin BE, et al. The prevalence and impact of respiratory symptoms in asthmatics and non-asthmatics during deployment. *Mil Med*. 2007;172:1264–1269.

23. Armed Forces Health Surveillance Center. *Epidemiological Studies of Health Outcomes Among Troops Deployed to Burn Pit Sites*. Silver Spring, MD: Naval Health Research Center/The U.S. Army Public Health Command (Provisional); 2010.

24. Leardman CA, Smith B, Smith TC, et al. Smallpox vaccination: comparison of self-reported and electronic vaccine records in the Millennium Cohort Study. *Hum Vaccin.* 2007;3:245–251.

25. Smith B, Chu LK, Smith TC, et al. Challenges of self-reported medical conditions and electronic medical records among members of a large military cohort. *BMC Med Res Methodol.* 2008;8:37.

26. Szema AM, Peters MC, Weissinger KM, Gagliano CA, Chen JJ. New-onset asthma among soldiers serving in Iraq and Afghanistan. *Allergy Asthma Proc*. 2010;31:67–71.

27. Szema AM, Salihi W, Savary K, Chen JJ. Respiratory symptoms necessitating spirometry among soldiers with Iraq/Afghanistan war lung injury. *J Occup Environ Med*. 2011;53:961–965.

28. Abraham JH, Baird CP. A case-crossover study of ambient particulate matter and cardiovascular and respiratory medical encounters among US military personnel deployed to southwest Asia. *J Occup Environ Med*. 2012;54:733–739.

29. National Research Council. *Review of the Department of Defense Enhanced Particulate Matter Surveillance Program Report.* Washington, DC: The National Academies Press; 2010:10–11, 51.