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Besa Smith
Charlene A. Wong
Edward J. Boyko
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Naval Health Research Center
140 Sylvester Road
San Diego, California 92106-5321

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Besa Smith, MPH, PhD, Charlene A. Wong, MPH, Edward J. Boyko, MD, MPH, Christopher J. Phillips, MD, MPH, Gary D. Gackstetter, DVM, MPH, PhD, Margaret A.K. Ryan, MD, MPH, and Tyler C. Smith, MS, PhD; for the Millennium Cohort Study Team

Objective: To investigate respiratory illnesses and potential open-air burn pit exposure among Millennium Cohort participants who deployed to Iraq or Afghanistan. **Methods:** Using multivariable logistic regression, newly reported chronic bronchitis or emphysema, newly reported asthma, and self-reported respiratory symptoms and possible burn pit exposure within 2, 3, or 5 miles were examined among Army and Air Force deployers surveyed in 2004 to 2006 and 2007 to 2008 ($n = 22{,}844$). **Results:** Burn pit exposure within 3 or 5 miles was not associated with respiratory outcomes after statistical adjustment. Increased symptom reporting was observed among Air Force deployers located within 2 miles of Joint Base Balad; however, this finding was marginally significant with no evidence of trend. **Conclusion:** In general, these findings do not support an elevated risk for respiratory outcomes among personnel deployed within proximity of documented burn pits in Iraq.

The acute and long-term respiratory health effects potentially associated with military deployment to the current operations in Iraq and Afghanistan continue to generate concern.[1–4] Adverse respiratory health experienced postdeployment may be attributed to specific exposures incurred while deployed.[5] One such exposure is the open-air burning of trash and other waste, which has garnered both media[6–9] and military attention.[4,10,11] Although the extent of the chemicals released in these burn pits is unknown, a recent ambient air sampling effort performed in select Middle East regions revealed smoke from burn pits as one major source of air pollution in deployed environments.[12] A number of pollutants including dioxins, carbon monoxide, volatile organic compounds, and respirable particulate matter may be produced from burning solid waste in open pits.[10,11] Some of these pollutants are well-recognized carcinogens, whereas others are known to irritate the respiratory system causing acute cough or shortness of breath, pneumonia, and chronic bronchitis, especially when exposures are recurring and at relevant concentrations.[13–16]

Although no known long-term health risks from burn pit smoke exposure have been identified, researchers have reported that exposure may cause transient coughing and irritation of the eyes or nose[10,11] as well as shortness of breath in healthy individuals.[10] In a sample of more than 15,000 military personnel who deployed to operations in Iraq or Afghanistan, 69% had reported experiencing respiratory illness, with more than 17% requiring medical care.[2] Moreover, military media reports have continued to surface with claims from troops, as well as veterans, implicating exposure to burn pits for ailments including breathing problems, asthma-like symptoms, bronchiolitis, and other pulmonary pathology.[8,9] Although evidence directly associating service members' claims of long-term illness with burn pit exposure has not been established, it is important for this association to be investigated further for the purpose of establishing future health care needs and planning for the care of returning troops.

To understand the effects burn pit exposure may have on respiratory health, the objective of this study was to examine the association between respiratory illness and exposure within 2-, 3-, and 5-mile radii of documented open-air burn pits among a large group of Army and Air Force personnel who deployed to operations in Iraq or Afghanistan. Participants were from the Millennium Cohort Study, a 21-year longitudinal study designed to investigate long-term health consequences of military service. The prospective design of the study allows for the surveillance of respiratory symptoms and some chronic respiratory conditions with longer latency while adjusting for potential confounders, including smoking behavior.

MATERIALS AND METHODS

Study Population

Launched in July 2001, the Millennium Cohort Study obtains follow-up survey data every 3 years until 2022 from participants during active duty and following separation from military service.[17–19] The Cohort composition reflects a population-based, stratified random sample of US military personnel from all service branches and components with more than 150,000 consented participants. The population for this report comprised participants who enrolled in the study between July 2001 and June 2003 ($n = 77{,}047$) or

From the Department of Deployment Health Research (Drs B Smith, Phillips, and TC Smith, and Ms Wong), Naval Health Research Center, San Diego, Calif; Seattle Epidemiologic Research and Information Center (Dr Boyko), Department of Veterans Affairs Puget Sound Health Care System, Seattle, Wash; Analytic Services Inc (Dr Gackstetter), Arlington, Va; Occupational Health Department (Dr Ryan), Naval Hospital Camp Pendleton, Camp Pendleton, Calif; and Department of Community Health (TC Smith), School of Health and Human Services, National University, La Jolla, Calif.

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In addition to the authors, the Millennium Cohort Study Team includes Paul J. Amoroso, Gregory C. Gray, Tomoko I. Hooper, Michelle Linfesty, James R. Riddle, Sheila Medina-Torne, and Timothy Wells.

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Address correspondence to: Besa Smith, MPH, PhD, Department of Defense Center for Deployment Health Research, Naval Health Research Center, 140 Sylvester Road, San Diego, CA 92106 mail to: besa.smith@med.navy.mil

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between June 2004 and February 2006 ($n = 31,110$), completed a questionnaire during the 2004–2006 and also during the 2007–2008 follow-up survey assessment cycles ($n = 63,590$), and deployed to Iraq or Afghanistan with their first deployment occurring after January 1, 2003. The study population was further restricted to Army and Air Force personnel only. Navy and Marine Corps personnel were excluded ($n = 5111$) because limited numbers of these personnel had deployed to the locations with documented burn pits under investigation in this study. Information about smoking status (nonsmoker, past smoker, consistent smoker, or resumed or new smoker), and aerobic activity of moderate or vigorous intensity were collected using the Cohort questionnaire. Demographic and military data for the study participants were provided by the Defense Manpower Data Center and included sex, birth year, marital status, race/ethnicity, education, service branch, military rank, pay grade, occupation, and date of military separation, if applicable. All covariates reflect status as of the 2004–2006 assessment with the exception of smoking status, which was prospectively updated using 2007–2008 survey data, and aerobic activity that was measured using the 2007–2008 survey instrument. Individuals with missing covariate data were excluded ($n = 283$).

Burn Pit Exposure Assessment

Deployment dates for service members who were located within 2-, 3-, or 5-mile radii of a documented, open-air burn pit at three different camps in Iraq (Joint Base Balad [JBB], Camp Taji, and Camp Speicher) between 2003 and 2008 were provided by the Defense Manpower Data Center. Deployment data for other operational locations in regions of Iraq or Afghanistan that did not contain burn pits were also provided to construct a comparison population. Three proxy measures for open-air burn pit exposure were created: (1) deployments near any of the three documented, open-air burn pit camps were compared with deployments to other locations that had no known burn pits; (2) cumulative days exposed within vicinity of any of the burn pits were compared with no days deployed to the burn pit locations; for those identified with burn pit exposure, overall cumulative days located at the documented burn pits were summed prior to and across the 2004 to 2006 and 2007 to 2008 assessment period and categorized into quartiles (3- and 5-mile radii of the burn pits: 1 to 56 days, 57 to 131 days, 132 to -209 days, and 210 days and more; 2-mile radius: 1 to 98 days, 99 to 131 days, 132 to 144 days, and 145 days and more); and (3) to measure whether a specific burn pit site was associated with risk, deployment to one of the three sites was compared with deployments to other locations with no burn pits, where specific burn pit sites were modeled separately and individually. Participants who deployed to multiple burn pit locations were categorized on the basis of the camp with the greatest exposure determined by the campsite with the longest deployment length, in days.

Respiratory Outcomes

Three self-reported respiratory outcomes were explored: (1) newly reported chronic bronchitis or emphysema, (2) newly reported asthma, and (3) self-reported respiratory symptoms of persistent or recurring cough or shortness of breath. On both the 2004 to 2006 and 2007 to 2008 survey assessments, participants were asked, "In the last 3 years, has your doctor or other health professional ever told you that you have any of the following conditions?" Possible responses included chronic bronchitis, emphysema, and asthma. Chronic bronchitis and emphysema were combined because of the pathogenesis of these diseases and the low prevalence of these conditions. Participants were also questioned about persistent or recurring problems of symptoms that included cough or shortness of breath. Newly reported chronic bronchitis or emphysema and newly reported asthma were prospectively examined and defined as endorsement of the conditions in the 2007 to 2008 survey with no previous endorsement among those with data available. Respiratory symptoms at enrollment in the study were measured over the previous 12 months; therefore, we were unable to ascertain presence of such symptoms prior to 12 months before enrollment. For this reason, incidence at follow-up could not definitively be measured. As such, self-reported respiratory symptoms were modeled at the 2007 to 2008 assessment adjusting for presence of symptoms in 2004 to 2006.

Statistical Analyses

Descriptive statistics were performed comparing personnel deployed to the burn pit sites with those deployed to other operational locations in regions of Iraq or Afghanistan with no known burn pits. Univariate analyses were performed to investigate the unadjusted associations between respiratory outcomes and covariates with the retention of statistically significant covariates ($P < 0.10$) to be included in multivariable analyses. Manual backward logistic regression was used to investigate confounding. Covariates were considered confounders if they changed the measure of association between burn pit exposure and the outcome by more than 10% and retained in the final multivariable models. Separate models were constructed to compare the odds of association between each respiratory outcome and each proxy measure assessing open-air burn pit exposure while adjusting for all demographic, behavioral, and military covariates. Multicollinearity was addressed using a variation inflation factor greater than 4 to indicate a potential problem.[20] Results presented in this report focus on burn pit exposure within 3 miles but additionally report the findings for analyses examining associations with burn pit exposure within the radial distances of 2 and 5 miles. The 2-mile analysis was restricted to newly reported respiratory outcomes among Air Force members because of small numbers in the 2-mile radius.

Further analyses were performed. Primary analyses were repeated to investigate whether outcome reporting differed by military service status and to examine the association between burn pit exposure and newly reported respiratory symptoms among those with no previous symptoms. Furthermore, to compare with a control population without known exposure to open-air burn pits, an additional analysis investigated Camp Arifjan in Kuwait. Camp Arifjan is located within the geographical region of the three burn pit sites, thus having meteorological conditions similar to the three burn pit sites, but lacks documented burn pits. Statistical significance for measures of association was designated at $P < 0.05$. Statistical analyses were performed using SAS version 9.2 (SAS Institute, Inc, Cary, NC).

The study protocol was approved by the Institutional Review Board of the Naval Health Research Center, and the research was conducted in compliance with all applicable federal regulations governing the protection of human subjects in research (protocol NHRC.2000.0007).

RESULTS

After exclusions, there were 22,844 Army and Air Force members in this study who deployed to operations in Iraq or Afghanistan between 2003 and 2008. This deployed population included more than 3000 personnel who deployed within 3- and 5-mile radii of a burn pit and more than 900 Air Force personnel who deployed within 2 miles of the JBB burn pits. From the 22,844 deployed members, separate populations were constructed for each respiratory outcome with additional exclusions. For respiratory symptoms, those with missing data on cough or shortness of breath at 2004 to 2006 or 2007 to 2008 (n = 547) were excluded, leaving 22,297 deployers of which 3585 personnel had deployed to locations with documented burn pits (Table 1). For the newly reported outcomes, those with missing data or who had reported the respective condition prior to the 2007 to 2008 period were excluded. Comparing burn pit exposed and nonexposed groups, we observed similar proportions for newly reported chronic bronchitis or emphysema (1.5% vs 1.6%,

TABLE 1. Characteristics of Deployed Army and Air Force Personnel in Relation to Exposure Within a 3-Mile Radius of a Documented Open-Air Burn Pit, The Millennium Cohort Study ($N = 22,297$)

Characteristic	Deployed Within 3 Miles of a Burn Pit ($n = 3,585$)	Other Deployed Location* ($n = 18,712$)
Sex		
Male	2644 (73.7)	14,197 (75.9)
Female	941 (26.3)	4515 (24.1)
Birth year		
Before 1960	228 (6.4)	2332 (12.5)
1960–1969	1036 (28.9)	5839 (31.2)
1970–1979	1335 (37.2)	6441 (34.4)
1980 and later	986 (27.5)	4100 (21.9)
Race/ethnicity		
White, non-Hispanic	2422 (67.6)	13,189 (70.5)
Black, non-Hispanic	445 (12.4)	1964 (10.5)
Asian/Pacific Islander	384 (10.7)	1910 (10.2)
Hispanic	265 (7.4)	1259 (6.7)
Other	69 (1.9)	390 (2.1)
Education		
High school or less	2390 (66.7)	11,198 (59.8)
Some college/Bachelor's degree	958 (26.7)	5594 (29.9)
Postgraduate degree	237 (6.6)	1920 (10.3)
Marital status		
Currently married	2027 (56.5)	11,175 (59.7)
Never married	1353 (37.8)	6369 (34.0)
No longer married	205 (5.7)	1168 (6.3)
Smoking status†		
Nonsmoker	1952 (54.5)	10,320 (55.1)
Consistent smoker	856 (23.9)	4179 (22.3)
Past smoker	625 (17.4)	3634 (19.5)
Resumed/new smoker	152 (4.2)	579 (3.1)
Aerobic activity‡		
Meets standards	2100 (58.6)	10,024 (53.6)
Does not meet standards	1309 (36.5)	7822 (41.8)
Cannot do	176 (4.9)	866 (4.6)
Service component		
Active duty	1977 (55.1)	9278 (49.6)
Reserve/National Guard	1608 (44.9)	9434 (50.4)
Military pay grade		
Enlisted	2747 (76.6)	13,709 (73.3)
Officer	838 (23.4)	5003 (26.7)
Service branch		
Army	2562 (71.5)	12,037 (64.3)
Air Force	1023 (28.5)	6675 (35.7)
Occupation		
Combat specialists	654 (18.2)	4175 (22.2)
Health care	362 (10.1)	1565 (8.4)
Electronic equipment repair	322 (9.0)	1563 (8.4)
Electrical/mechanical equipment repair	607 (17.0)	2435 (13.0)
Communications/intelligence	268 (7.5)	1593 (8.5)
Functional support and administration	604 (16.8)	3362 (18.0)
Craft workers	134 (3.7)	603 (3.2)
Service and supply	372 (10.4)	2238 (12.0)
Other technical and allied specialists	110 (3.1)	515 (2.8)
Students, trainees, and others	152 (4.2)	663 (3.5)

Characteristics in the table are based on the study population used for the respiratory symptoms model. All values are given as *n* (%). All pairwise comparisons were significant at $P < 0.05$.

*Deployment to other locations in support of operations in Iraq or Afghanistan outside a 3-mile radius of the documented burn pit sites.

†Smoking status was prospectively assessed using data from both 2004–2006 and 2007–2008 survey assessments.

‡Aerobic activity was assessed in 2007–2008 and standards were defined using Healthy People 2010 guidelines.

respectively), newly reported asthma (1.7% vs 1.6%), and respiratory symptoms in 2007 (21.3% vs 20.6%). Using the respiratory symptoms population, those deployed within proximity to documented burn pits were proportionately more likely to be younger, less educated, aerobically active, active duty, and Army personnel compared with deployers to other locations (Table 1).

The average elapsed time between follow-up surveys was 2.9 years. At the end of follow-up, and after adjusting for demographic, behavioral, and military covariates, those significantly at risk for newly reported chronic bronchitis or emphysema included women (adjusted odds ratio [AOR], 1.77; 95% confidence interval [95% CI], 1.36 to 2.30), consistent smokers (AOR, 1.61; 95% CI, 1.24 to 2.10), and Army personnel (AOR, 1.82; 95% CI, 1.38 to 2.41), whereas those at reduced risk included younger individuals (AOR, 0.59; 95% CI, 0.36 to 0.96) and those who engaged in some level of aerobic activity regardless of meeting standards (Table 2). Those significantly at risk for newly reported asthma also included women (AOR, 1.78; 95% CI, 1.38 to 2.32) and Army personnel (AOR, 2.27; 95% CI, 1.70 to 3.03), whereas both those who did and did not meet standards for aerobic activity were at reduced risk for asthma compared with those who could not perform aerobic activity. After we adjusted for respiratory symptoms in 2004 to 2006 and all other covariates, those significantly at risk for respiratory symptoms in 2007–2008 were women (AOR, 1.11; 95% CI, 1.02 to 1.22), Hispanics (AOR, 1.18; 95% CI, 1.04 to 1.35), smokers (past or current), active duty (AOR, 1.18; 95% CI, 1.09 to 1.27), enlisted (AOR, 1.47; 95% CI, 1.28 to 1.68), and Army personnel (AOR, 1.90; 95% CI, 1.75 to 2.07), whereas those at reduced risk were younger, had a postgraduate degree (AOR, 0.80; 95% CI, 0.66 to 0.96), and were aerobically active at some level regardless of meeting standards.

After we adjusted for for all covariates, we found that deployment within 3 miles of the burn pits did not significantly increase the risk for newly reported chronic bronchitis or emphysema (AOR, 0.91; 95% CI, 0.67 to 1.24), newly reported asthma (AOR, 0.94; 95% CI, 0.70 to 1.27), or self-reported respiratory symptoms (AOR, 1.03; 95% CI, 0.94 to 1.13) when compared with deployments to other regions of Iraq or Afghanistan with no documented burn pits (Table 2). When investigating the effect of cumulative days exposed within a 3-mile radius of the burn pits, increasing days near the burn pits did not significantly increase the risk for newly reported chronic bronchitis or emphysema ($P = 0.76$), newly reported asthma ($P = 0.63$), or self-reported respiratory symptoms ($P = 0.94$) after adjustment (Table 3). When considering specific camp location, the majority of Army and Air Force personnel within proximity of a burn pit were located within 3 miles of JBB (9.7% to 9.9%), followed by Camp Speicher (3.6% to 3.7%) and Camp Taji (2.5% to 2.6%). Specific camp location, however, was not associated with elevated risk for newly reported chronic bronchitis or emphysema ($P = 0.27$), newly reported asthma ($P = 0.22$), or self-reported respiratory symptoms ($P = 0.82$) (Table 4).

As stated, alternate radii for deployment location distance from burn pit sites were also investigated. Findings of no association, including deployment status, cumulative deployment length, and camp location were consistent when examining the risk within 5-miles of the burn pits. Within a 2-mile radius of the burn pit at JBB, however, Air Force personnel ($n = 7968$) were at increased risk for respiratory symptoms (AOR, 1.24; 95% CI, 1.01 to 1.52) when compared with those deployed to other locations. There was no significant trend in cumulative deployment length within 2 miles of JBB when investigated (data not shown). Army personnel could not be assessed in this analysis of exposure within a 2-mile radius because of insufficient sample size.

Analyses using those deployed to Camp Arifjan as the reference group revealed no significant increase in risk for newly reported chronic bronchitis or emphysema ($P = 0.35$), newly reported asthma ($P = 0.22$), or self-reported respiratory symptoms ($P = 0.88$) among those who deployed within 3 miles of a burn pit at JBB, Camp Speicher, or Camp Taji.

Investigations from the additional analyses identified that 9% had separated from military service by the 2007 to 2008 follow-up assessment. Findings remained unchanged when the covariate indicating military separation was included in the multivariable models with no association between deployment and respiratory outcome (newly reported chronic bronchitis or emphysema, $P = 0.67$; newly reported asthma, $P = 0.85$; self-reported respiratory symptoms, $P = 0.46$).

For analyses examining newly reported respiratory symptoms, an additional 4607 participants who reported prior symptoms at baseline were excluded. Among the 17,690 remaining, 2486 newly reported respiratory symptoms (14%). Findings remained consistent. Deployment within 3 miles of the burn pits was not statistically associated with an increase in odds of newly reported symptoms when compared with those who deployed to other locations ($P = 0.71$). No significant associations were seen with cumulative days exposed ($P = 0.63$) nor with deployment to a specific burn pit campsite ($P = 0.97$).

DISCUSSION

The current findings from this investigation suggest that deployment location within 3 miles of a documented burn pit was not significantly associated with increased risk for respiratory symptoms or conditions when compared with deployment beyond 3 miles of the burn pits. The overall findings did not change when evaluating the risk within a 5-mile radius. Risk for respiratory symptoms or conditions did not increase when number of days deployed within 3 or 5 miles of the burn pits or deployments to specific burn pit camps were considered. This study did, however, show a marginally significant increased risk for respiratory symptoms among a subpopulation of only Air Force personnel who had deployed within a 2-mile radius of the burn pit at JBB when compared with Air Force personnel who deployed to locations with no documented burn pits. These data offer the first investigation into an association between possible burn pit exposure and subsequent respiratory conditions at a population level independent of smoking.

Starting in 2003, JBB was known to house the largest burn pit in Iraq, where several tons of solid waste material including plastics, metals (eg, aluminum cans), rubber, paints, solvents, petroleum, oil, lubricants, munitions and wood waste were burned daily until the burn pit was shutdown in late 2009.[21] Because burn pits do not operate under highly controlled conditions, numerous pollutants are generated and may include particulate matter, polycyclic aromatic hydrocarbons, volatile organic compounds, carbon monoxide, hexachlorobenzene, and ash.[10,11,22] Unlike municipal combustors, open-air burn pits do not reach high temperatures,[4,22] which may increase the percentages of incomplete combustion by-products. Dioxins are produced in small amounts in almost all burning processes and can also be produced in elevated levels with increased combustion of plastic waste (such as discarded drinking water bottles).[21,22] It has been reported that smoke emitted from the burn pit would drift over living areas under various weather conditions,[21] which may explain the increase in symptom reporting among Air Force personnel found in the current study.[4,22]

Exposure data were from JBB, Camp Speicher, and Camp Taji, which reportedly contained the largest burn pits and therefore would result in the highest likelihood of burn pit exposure. Data to assess possible burn pit exposure over the entire theater of operations were not available for this analysis. Therefore, we further examined whether these personnel with deployments within 3 miles of the burn pits may be at greater risk when compared with those deployed to Camp Arifjan, which is located within the geographical region of the three burn pit sites and shares similar meteorological conditions but contains no documented burn pits. Its trash is transported off the base

TABLE 2. Adjusted Odds of Respiratory Outcomes Among Army and Air Force Personnel by Deployment Within 3 Miles of a Documented Open-Air Burn Pit, the Millennium Cohort Study

	Chronic Bronchitis or Emphysema* (*N* = 20,676)	Asthma* (*N* = 20,077)	Respiratory Symptoms† (*N* = 22,297)
3-mile radius			
Other deployment‡	1.00§	1.00§	1.00§
Exposed deployment	0.91 (0.67–1.24)	0.94 (0.70–1.27)	1.03 (0.94–1.13)
Sex			
Male	1.00§	1.00§	1.00§
Female	1.77 (1.36–2.30)	1.78 (1.38–2.32)	1.11 (1.02–1.22)
Birth year			
Before 1960	1.00§	1.00§	1.00§
1960–1969	0.82 (0.57–1.18)	1.15 (0.75–1.75)	0.96 (0.84–1.09)
1970–1979	0.73 (0.50–1.08)	0.90 (0.58–1.40)	0.79 (0.69–0.91)
1980 and later	0.59 (0.36–0.96)	0.72 (0.43–1.21)	0.82 (0.70–0.97)
Race/ethnicity			
White, non-Hispanic	1.00§	1.00§	1.00§
Black, non-Hispanic	0.85 (0.59–1.24)	0.84 (0.58–1.22)	1.04 (0.92–1.16)
Asian/Pacific Islander	1.03 (0.68–1.56)	0.90 (0.58–1.42)	1.00 (0.87–1.15)
Hispanic	1.04 (0.68–1.59)	1.25 (0.85–1.84)	1.18 (1.04–1.35)
Other	1.11 (0.45–2.72)	0.86 (0.32–2.36)	0.94 (0.70–1.27)
Education			
High school or less	1.00§	1.00§	1.00§
Some college/Bachelor's degree	1.06 (0.78–1.45)	0.90 (0.65–1.23)	0.93 (0.84–1.03)
Postgraduate degree	1.13 (0.66–1.93)	0.71 (0.38–1.32)	0.80 (0.66–0.96)
Marital status			
Never married	1.00§	1.00§	1.00§
Currently married	1.17 (0.87–1.57)	0.78 (0.59–1.03)	1.03 (0.94–1.13)
No longer married	1.15 (0.72–1.85)	0.91 (0.57–1.46)	1.01 (0.86–1.19)
Smoking status			
Nonsmoker	1.00§	1.00§	1.00§
Consistent smoker	1.61 (1.24–2.10)	0.94 (0.71–1.24)	1.31 (1.20–1.44)
Past smoker	0.93 (0.68–1.28)	1.02 (0.76–1.38)	1.12 (1.01–1.23)
Resumed/new smoker	0.89 (0.45–1.76)	0.56 (0.26–1.21)	1.28 (1.06–1.55)
Aerobic activity			
Cannot do	1.00§	1.00§	1.00§
Meets standards	0.37 (0.26–0.53)	0.40 (0.28–0.58)	0.45 (0.39–0.52)
Does not meet standards	0.44 (0.31–0.64)	0.46 (0.32–0.67)	0.51 (0.44–0.59)
Service component			
Reserve/National Guard	1.00§	1.00§	1.00§
Active duty	0.98 (0.77–1.26)	1.08 (0.84–1.37)	1.18 (1.09–1.27)
Military pay grade			
Officer	1.00§	1.00§	1.00§
Enlisted	1.31 (0.86–1.97)	1.49 (0.97–2.30)	1.47 (1.28–1.68)
Service branch			
Air Force	1.00§	1.00§	1.00§
Army	1.82 (1.38–2.41)	2.27 (1.70–3.03)	1.90 (1.75–2.07)
Occupation			
Combat specialists	1.00§	1.00§	1.00§
Health care	1.38 (0.89–2.13)	1.25 (0.79–1.98)	0.88 (0.75–1.02)
Electronic equipment repair	1.20 (0.75–1.91)	1.00 (0.60–1.65)	1.14 (0.99–1.32)
Electrical/mechanical equipment repair	1.05 (0.68–1.62)	1.48 (0.99–2.20)	1.06 (0.94–1.21)
Communications/intelligence	1.11 (0.70–1.77)	1.44 (0.93–2.21)	1.11 (0.96–1.27)
Functional support and administration	1.06 (0.72–1.57)	0.82 (0.54–1.25)	1.07 (0.95–1.21)
Craft workers	1.52 (0.83–2.80)	0.83 (0.39–1.78)	1.20 (0.98–1.48)

(*Continued*)

TABLE 2. (*Continued*)

	Chronic Bronchitis or Emphysema* (*N* = 20,676)	Asthma* (*N* = 20,077)	Respiratory Symptoms† (*N* = 22,297)
Service and supply	1.16 (0.78–1.75)	1.09 (0.72–1.65)	1.12 (0.99–1.27)
Other technical and allied specialists	1.18 (0.59–2.35)	1.22 (0.63–2.39)	0.95 (0.76–1.19)
Students, trainees, and other	0.64 (0.27–1.50)	1.65 (0.91–2.98)	0.88 (0.70–1.10)
Self-reported respiratory symptoms‖			
No	–	–	1.00§
Yes	–	–	4.85 (4.49–5.25)

Models were adjusted for sex, birth year, marital status, race/ethnicity, education, smoking status, aerobic activity, service branch, service component, military rank, and occupation. For respiratory symptoms outcome, adjustment for prevalence of respiratory symptoms reported at 2004–2006 was included. All values are given as adjusted odds ratio (95% confidence interval).

*All participants in respective models were disease free prior to 2007–2008.

†Respiratory symptoms were defined as persistent or recurring cough or shortness of breath self-reported at 2007–2008.

‡Deployment to other locations in support of operations in Iraq or Afghanistan outside a 3-mile radius of the documented burn pits.

§Indicates reference category.

‖Measured at 2004–2006 assessment.

TABLE 3. Adjusted Odds of Reported Respiratory Outcomes Among Army and Air Force Personnel in Relation to Cumulative Days Deployed Within 3 Miles of a Documented Open-Air Burn Pit, the Millennium Cohort Study

	Chronic Bronchitis or Emphysema* (*N* = 20,676)		Asthma* (*N* = 20,077)		Respiratory Symptoms† (*N* = 22,297)	
	n (%)	AOR (95% CI)	*n* (%)	AOR (95% CI)	*n* (%)	AOR (95% CI)
Exposed days‡		*P* = 0.76		*P* = 0.63		*P* = 0.94
0§	17,348 (83.9)	1.00	16,857 (84.0)	1.00	18,712 (83.9)	1.00
1–56	850 (4.1)	1.00 (0.59–1.69)	826 (4.1)	0.71 (0.38–1.30)	908 (4.1)	0.98 (0.83–1.17)
57–131	829 (4.0)	0.63 (0.31–1.28)	799 (4.0)	0.77 (0.41–1.45)	897 (4.0)	1.05 (0.88–1.25)
132–209	820 (4.0)	1.10 (0.64–1.90)	795 (3.9)	1.15 (0.68–1.96)	899 (4.0)	1.05 (0.88–1.26)
≥210	829 (4.0)	0.90 (0.51–1.59)	800 (4.0)	1.14 (0.41–1.45)	881 (4.0)	1.03 (0.87–1.23)

Models were adjusted for sex, birth year, marital status, race/ethnicity, education, smoking status, aerobic activity, service branch, service component, military rank, and occupation. For respiratory symptoms outcome, adjustment for prevalence of respiratory symptoms reported at 2004–2006 was included. AOR, adjusted odds ratio; CI, confidence interval.

*All participants in respective models were disease free prior to 2007–2008.

†Respiratory symptoms were defined as persistent or recurring cough or shortness of breath self-reported at 2007–2008.

‡Categories found by computing quartiles of days exposed among those with identified deployments within a 3-mile radius of the burn pit sites.

§Indicates reference category.

TABLE 4. Adjusted Odds of Reported Respiratory Outcomes Among Army and Air Force Personnel Deployed Within 3 Miles of a Documented Open-Air Burn Pit, by Campsite, the Millennium Cohort Study

	Chronic Bronchitis or Emphysema* (*N* = 20,676)		Asthma* (*N* = 20,077)		Respiratory Symptoms† (*N* = 22,297)	
	n (%)	AOR (95% CI)	*n* (%)	AOR (95% CI)	*n* (%)	AOR (95% CI)
Campsite‡		*P* = 0.27		*P* = 0.22		*P* = 0.82
Other deployment§‖	17,348 (83.9)	1.00	16,857 (84.0)	1.00	18,712 (83.9)	1.00
Joint Base Balad	2,022 (9.8)	1.07 (0.74–1.54)	1,957 (9.7)	0.84 (0.56–1.25)	2,206 (9.9)	1.01 (0.90–1.14)
Taji	543 (2.6)	1.05 (0.55–2.01)	523 (2.6)	1.53 (0.91–2.58)	568 (2.5)	1.10 (0.90–1.36)
Speicher	763 (3.7)	0.48 (0.22–1.02)	740 (3.7)	0.76 (0.42–1.38)	811 (3.6)	1.01 (0.85–1.21)

Models adjusted for sex, birth year, marital status, race/ethnicity, education, smoking status, aerobic activity, service branch, service component, military rank, and occupation. For the respiratory symptoms outcome, adjustment for prevalence of respiratory symptoms reported at 2004–2006 was included. AOR, adjusted odds ratio; CI, confidence interval.

*All participants in respective models were disease free prior to 2007–2008.

†Respiratory symptoms were defined as persistent or recurring cough or shortness of breath self-reported in 2007–08.

‡Participants who deployed to multiple burn pit locations were categorized on the basis of the camp with the greatest exposure determined by the campsite with the longest deployment length, in days.

§Deployment to other locations in support of operations in Iraq or Afghanistan outside a 3-mile radius of the documented burn pit campsites.

‖Indicates reference category.

for disposal elsewhere. Findings revealed that those who deployed within 3 miles of the burn pit sites were not at increased risk for the respiratory outcomes when compared with those deployed to Camp Arifjan. We also investigated whether military separation explained the lack of association between possible burn pit exposure at a 3-mile radius. Though service personnel in this study were on active duty or on active status with the Reserves or National Guard while deployed, almost 10% had separated by follow-up. These analyses, however, revealed no evidence to suggest that separation from service was acting as a confounder. In addition, when participants with baseline symptoms were removed, deployment within 3 miles of the burn pits did not reveal an increase in risk for new-onset respiratory symptoms.

Other findings from this study demonstrate that, in general, Army personnel were at greater risk for all three respiratory outcomes when compared with Air Force personnel. This is consistent with a recent report that found an increase in respiratory symptom reporting among land-based deployers.[5] This increase, however, does not seem to be attributed to deployment location within 3- or 5-mile radii of the documented burn pits. It may be that closer proximity to the burn pits showed similar findings of increased respiratory risk among land-based, deployed (Army or Marine Corps) Cohort members; however, further assessment was not possible because so few personnel were identified within a 2-mile radius of the documented burn pits. Women were also consistently at greater risk for all respiratory outcomes, a finding consistent with morbidity trends[23,24] and other published research.[25–28]

Occupational risk factors should also be considered. Considerable literature supports an association between respiratory illnesses and occupation. Occupational factors are estimated to account for 9% to 15% of cases of asthma in working-age adults, for both new-onset and recurrent diseases.[29] Occupational exposures defined as dust, gases, vapors, wet conditions, or extreme temperature have been associated with a higher risk of cough, asthma, chronic obstructive pulmonary disease, and diminished forced expiratory volume in 1 second and Functional Vital Capacity measured by pulmonary function testing.[30] A long list of organic and inorganic dusts and fumes have been associated with occupationally induced asthma acting through the immune system or as direct irritants to the respiratory mucosa.[31] Chronic respiratory illnesses have been associated with certain occupational exposures as well. Among Army Chemical Corp veterans who sprayed herbicide during the Vietnam War, an elevation in the standardized mortality ratio due to nonmalignant respiratory diseases was observed (standardized mortality ratio, 1.58; 95% CI, 1.08 to 2.23).[32] Thus, there is good reason for concern for potentially higher risk for respiratory illnesses after occupational exposures during deployments; however, we found no associations with potential burn pit exposures.

This study had some additional limitations not addressed earlier in the text. Respiratory conditions were self-reported and may over- or underrepresent the true burden of these conditions in this population. Clinical examinations to confirm self-reported symptoms and conditions were not conducted. As such, the self-reported respiratory outcomes included in this study may not equate with a physician's diagnosis. The survey instrument and collected data, however, have been validated, and self-reported data from this survey have been found reliable for many outcomes.[33–37] In addition, the short follow-up period (2.9 years on average) may only allow identification of acute conditions and may fail to account for chronic conditions that could develop over a longer time period. Limitations also exist surrounding the exposure assessment. Though an individual exposure assessment would be optimal, this was not available and therefore three different surrogate measures of exposure (proximal distance, cumulative days deployed, and deployments to specific burn pit sites) were examined. Proximity methods have been used in prior epidemiological studies[38–43] and assume that exposures decrease with increasing distance from the source.[44,45] This approach is limited in the assumption that subjects within a given distance of an exposure source are equally exposed, thereby increasing the potential for misclassification. Data on particulate matter characteristics and levels of exposure by individual service member beyond number of days deployed were not available. Although we were able to estimate an individual service member's exposure to a burn pit by space and time (within a radius around the pit for a discrete date interval) it is a broad and less than precise measure for true inhalation exposure and specific subgroups of these deployed personnel with extensive exposure may be at risk for respiratory ailments that were not identified in this study. Finally, many other unknown factors, such as the specific materials burned at the pit sites, prevailing wind speed and direction, how much time was spent outside a building or shelter versus inside (eg, a TemperTent, trailer, or building with filtered air), and whether the service member spent the majority of time away from the camp, would result in widely varying exposure estimates, which may result in misclassification of exposure status. Additional efforts should be directed toward individual level exposure assessment.

Despite these limitations, there are several important strengths to this study. Although direct quantitative measurements of environmental pollutants yield better accuracy for exposure estimation, such methods can be complex, expensive, and time-consuming,[46] thus limiting their use in theater. The use of proximity methods for identifying exposed populations is a simple, cost-effective approach and provides a rapid initial assessment especially in the current case where other exposure assessments were lacking, and there is little evidence of the short- and long-term effects of burn pit exposure. Also noteworthy is the population-based, longitudinal design of the Millennium Cohort Study that allows for prospective assessment of the same individuals from all service branches and service components, and was able to include individuals even after separation from military service. Use of self-reported data allowed for the evaluation of respiratory symptoms for early respiratory illness manifestation over analyses, based only on diagnoses through medical record data. Finally, the extensive data collected by the Millennium Cohort survey instruments provided the ability to control for multiple confounders including smoking status and physical activity, which is essential when considering respiratory ailments.

In conclusion, this study did not find a significant association between exposure within 3 miles of a documented open-air burn pit and respiratory symptoms or conditions, using several proxy measures of exposure including cumulative days deployed, which resulted in no established dose–response relationship. Increased symptom reporting was observed among Air Force personnel deployed within 2 miles of JBB, which may be a result of having been exposed to burn pit smoke; however, this finding was only marginally significant and not confirmed by our other results. The lack of a consistent association and dose–response relationship should be reassuring to the many service personnel who were deployed to these camps though further research is warranted. In the future, further data collection will allow for longitudinal analyses while adjusting for numerous time-varying covariates and will permit the assessment of respiratory illnesses characterized with longer induction or latency. Further research, including additional documented burn pit sites integrating particulate matter data, meteorological and wind data, and other in-theater exposures, should be conducted to understand both short- and long-term respiratory health issues potentially associated with open-air burn pit smoke exposure.

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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Naval Health Research Center
140 Sylvester Rd
San Diego, CA 92106-3521

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8. SPONSORING/MONITORING AGENCY NAMES(S) AND ADDRESS(ES)
Commanding Officer
Naval Medical Research Center
503 Robert Grant Ave
Silver Spring, MD 20910-7500

Chief, Bureau of Medicine and Surgery
(MED 00), Navy Dept
2300 E Street NW
Washington, DC 20372-5300

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14. ABSTRACT

Background
A number of pollutants including dioxins, carbon monoxide, volatile organic compounds, and respirable particulate matter may be produced from burning solid waste in open pits. Some of these pollutants are well-recognized carcinogens, while others are known to irritate the respiratory system causing acute cough or shortness of breath, pneumonia, and chronic bronchitis, especially when exposures are recurring and at relevant concentrations.

Methods
Using multivariable logistic regression, newly-reported chronic bronchitis or emphysema, newly-reported asthma, and self-reported respiratory symptoms and possible burn pit exposure within 2, 3, or 5 miles were examined among Army and Air Force deployers surveyed in 2004-06 and 2007-08 (n = 22,844).

Results
Burn pit exposure within 3 or 5 miles was not associated with respiratory outcomes after statistical adjustment. Increased symptom reporting was observed among Air Force deployers located within 2 miles of Joint Base Balad, however, this finding was marginally significant with no evidence of trend.

Conclusions
In general, these findings do not support an elevated risk for respiratory outcomes among personnel deployed within proximity of documented burn pits in Iraq.

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