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***C. J. Hansen
K. L. Russell, T. C. Smith
J. S. Neville, M. R. Krauss
M. A. K. Ryan .***



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***Naval Health Research Center
140 Sylvester Road
San Diego, California 92106***

Asthma hospitalizations among US military personnel, 1994 to 2004

Christian J. Hansen, BS*; Kevin L. Russell, MD, MTMH*; Tyler C. Smith, MS*;
James S. Neville, MD, MPH‡; Margot R. Krauss, MD, MPH†; and Margaret A. K. Ryan, MD, MPH*

Background: Acute asthma attacks strike unpredictably and may lead to hospitalization in otherwise healthy individuals. The burden of asthma hospitalization on the US health care system has greatly interested health care workers, many of whom see the incidence of asthma as increasing.

Objectives: To examine the annual incidence of hospitalization and the frequency of subsequent hospitalization for asthma among all active-duty US military personnel between 1994 and 2004 and to determine demographic and occupational risk factors of asthma hospitalization within this generally healthy US population.

Methods: Annual demographic and occupational data were combined with electronic hospitalization records for patients with a discharge diagnosis of asthma. Using Cox proportional hazard modeling, the authors investigated demographic and occupational risk factors for asthma hospitalization.

Results: Women, married persons, health care workers, enlisted personnel, US Army personnel, and older persons were found to have a significantly greater risk of asthma hospitalization. Yearly rates of hospitalization declined from 22.3 per 100,000 persons to 12.6 per 100,000 persons between 1994 and 2004.

Conclusions: Although these data have some limitations, they suggest that the burden of asthma hospitalizations in the large, healthy population of US military personnel has declined during the last decade. The decrease in hospitalization potentially reflects improved outpatient management strategies.

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INTRODUCTION

Asthma is characterized by inflammation and reversible reactivity of the airways, causing varying degrees of respiratory compromise, and is one of the most common diseases that affects Americans.¹ Asthma attacks can strike unpredictably and may necessitate hospitalization for otherwise healthy individuals. The Centers for Disease Control and Prevention published data on prevalence, hospitalizations, and deaths due to asthma, indicating significant increases in the prevalence of asthma in the United States during the 1990s.¹ However, during the second half of the 1990s, mortality resulting from asthma in the US population declined in some demographic groups.^{2,3} By preventing hospitalization or reducing symptoms to a subclinical level, differing effectiveness and application of pharmaceutical therapies developed and first dispensed during the study period compound the complexities of accurately estimating the total burden of asthma.^{4,5}

In military settings, asthma presents potentially severe consequences. Personnel with asthma can experience unpredictable limitations in capacity for physical work, compromising individual and group operational requirements. The exacerbation and impact of asthma in this environment prompted the US Department of Defense (DoD) to reconsider its medical standards for entry into service, including waivers issued for known preexisting asthmatic conditions.⁶ Although waivers are currently available for recruits with a history of childhood asthma (no occurrence after the 13th birthday),^{6–8} during the study period, entrance standards excluded anyone with reliably diagnosed asthma from entering active-duty service.^{7–9} After 6 months, military retention standards apply, allowing personnel with asthma to remain on active duty.

It has been suggested that some activities, such as deployment to new environments, may be potential risk factors for asthma in military personnel.¹⁰ However, previous epidemiologic studies that investigated exposures of veterans of the 1991 Gulf War, including oil well fire smoke¹¹ and chemical munitions demolition operations,¹² found no significant association with asthma.

Trends of asthma in military settings have been of interest outside the United States as well. An increase in the prevalence of asthma was found in a study of potential Belgian military conscripts from 1978 to 1991¹³ and in Italian conscripts from 1983 to 1995.¹⁴ Although rates of asthma hospitalization among some populations have increased significantly,¹⁵ other studies indicate rates have stabilized or declined.^{16,17}

* Department of Defense Center for Deployment Health Research, Naval Health Research Center, San Diego, California.

† Walter Reed Army Institute of Research, Bethesda, Maryland.

‡ Air Force Institute for Operational Health, San Antonio, Texas.

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Table 1. Demographic Characteristics of Active-Duty Personnel Hospitalized for Asthma Compared With All Other US Military Personnel, 1994–2004

Characteristics	Total population, No. (%) (N = 4,777,880)	Asthma patients, No. (%) (n = 3,212)
Sex		
Men	4,107,262 (86.0)	2,420 (75.3)
Women	670,281 (14.0)	791 (24.6)
Marital status		
Single	3,243,458 (67.9)	1,713 (53.3)
Married	1,534,422 (32.1)	1,499 (46.7)
Age group, y		
17–22	1,971,257 (41.3)	1,045 (32.5)
23–28	1,573,138 (32.9)	794 (24.7)
29–34	620,380 (13.0)	498 (15.5)
35–65	613,105 (12.8)	875 (27.2)
Branch of service		
US Army	1,745,446 (36.5)	1,589 (49.5)
US Navy	1,262,553 (26.4)	749 (23.3)
US Air Force	1,039,953 (21.8)	615 (19.1)
US Marines	639,318 (13.4)	240 (7.5)
Race/ethnicity		
White	3,313,437 (69.3)	1,737 (54.1)
Black	885,901 (18.5)	1,072 (33.4)
Hispanic	327,628 (6.9)	211 (6.6)
Other	250,914 (5.3)	192 (6.0)
Home state		
Northwest	590,079 (12.4)	318 (9.9)
Northeast	1,611,164 (33.7)	1,130 (35.2)
Southeast	805,295 (16.9)	632 (19.7)
Southwest	1,006,111 (21.1)	690 (21.5)
Non-United States	765,231 (16.0)	442 (13.8)
Pay grade		
Enlisted	4,354,103 (91.1)	2,990 (93.1)
Officer	423,777 (8.9)	222 (6.9)
Occupational category		
Combat specialists	1,320,526 (27.6)	713 (22.2)
Electronic repair	285,087 (6.0)	181 (5.6)
Communications and intelligence	397,799 (8.3)	297 (9.2)
Health care	199,790 (4.2)	261 (8.1)
Other technical and allied specialists	91,204 (1.9)	63 (2.0)
Functional support and administration	549,793 (11.5)	592 (18.4)
Electrical/mechanical equipment repair	678,289 (14.2)	422 (13.1)
Crafts workers	117,335 (2.5)	69 (2.1)
Service and supply	374,990 (7.8)	316 (9.8)
Trainees, other	692,494 (14.5)	268 (8.3)

Although it has been estimated that up to 25% of asthma is occupationally related,^{18,19} with some occupations associated with an increased risk of developing asthma,^{20–22} results have been mixed and risks difficult to quantify.^{18,23,24} The current study investigates the association of incident asthma hospi-

talizations with certain demographic variables among active-duty military members during the last decade.

MATERIALS AND METHODS

Study Population

For this retrospective cohort study, the observed population included 4.7 million persons (33.6 million person-years observed), representing all personnel from the US Army, US Navy, US Air Force, and US Marines on active duty between 1994 and 2004. The Defense Manpower Data Center (Monterey Bay, CA) provided demographic information for all active-duty US military personnel. Since asthma varies by age, sex, and race, these variables were included in this investigation.^{25–28} Race/ethnicity was standardized into 4 categories: white, black, Hispanic, and other. Home state at entrance to military service was defined as 5 geographical categories (Northeast, Southeast, Northwest, Southwest, and noncontinental United States). Marital status at the time of entry into the observation period was defined as married or unmarried.

Occupational factors evaluated included branch of service (US Army, US Navy, US Air Force, or US Marines), military pay grade (officer, enlisted), and DoD primary occupation at time of entry. Ten categories were defined: combat specialists, electronic repair, communications and intelligence, health care, electrical and mechanical equipment repair, crafts workers, functional support and administration, service and supply, other technical and allied specialists, and a group including students, prisoners, and other personnel.²⁹

Hospitalization Data

Routinely collected military hospitalization data for active-duty military members were obtained from the Standard Inpatient Data Record and the Civilian Health and Medical Program of the Uniformed Services/Tri-Care Health Care Service Record. These computerized databases include standardized discharge diagnoses for hospitalizations within the Military Health Services System and for hospitalizations billed by private facilities. Each record contains summaries that include dates of admission and discharge, up to 8 procedural codes, and up to 8 individual discharge diagnoses for each encounter. This standardized reporting method ensures uniform data collection across military services. The military hospitalization file has been maintained in electronic form since October 1, 1988, for all inpatient health care provided worldwide in any US military treatment facility. The civilian hospitalization file contains inpatient encounters at private health care facilities since October 1, 1993. Personal identifiers, including Social Security numbers, are used to identify patients within both files. These data are similar to civilian and Medicaid medical records currently used in asthma surveillance.^{30,31} Specific diagnoses are currently coded according to the *International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)*.³²

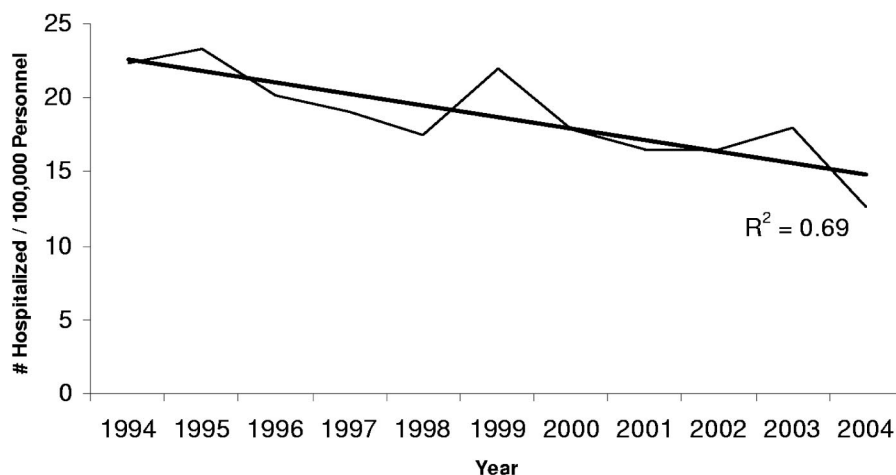


Figure 1. Annual rates of first asthma hospitalization per 100,000 persons, 1994 to 2004.

Outcome Measures

All active-duty personnel admitted as inpatients to a military hospital or a private treatment facility sponsored by the DoD health care system with a primary discharge diagnosis of asthma (ICD-9-CM code 493.XX) were identified for the period January 1, 1994, through December 31, 2004. Since this study attempted to identify patterns and risk factors associated with new-onset asthma, persons with a record of hospitalization for asthma during the 4 years preceding the study were excluded from the analyses. In an effort to obtain more accurate estimation of risks associated with incident asthma, we approximated incident cases using first hospitalization. Subsequent hospitalization was evaluated in a separate analysis, allowing multiple hospitalizations per person, provided the hospitalizations were 7 or more days apart.

Statistical Analysis

After descriptive investigation of population characteristics, univariate analyses were performed to evaluate the significance of associations between demographic and occupational variables with asthma hospitalization. Using regression diagnostics, colinearity among variables was investigated. The

Cox proportional hazards time-to-event modeling was used to evaluate asthma hospitalizations of all active-duty US military personnel, while accounting for delayed entry into and attrition from active-duty service during the 11-year follow-up period. Follow-up time was calculated from January 1, 1994, or time of entry into service if occurring after this date until first hospitalization with asthma, separation from active-duty service, or December 31, 2004, whichever occurred first. The saturated Cox regression model was reduced by a manual backward stepwise elimination approach removing those variables that were insignificant at the $\alpha = .05$ level and not confounding the other measures of association. Additionally, cumulative probability of hospitalization with asthma from entry into follow-up period was graphed.

For the estimates of annual prevalence, all hospitalizations for asthma were compared with the total force population for each year and a trend was estimated using linear regression. For this aspect of the analysis, counting multiple hospitalizations per person was allowed to provide a comparison of subsequent hospitalizations for asthma each year. Statistical modeling to produce adjusted hazard ratios (HRs), associated

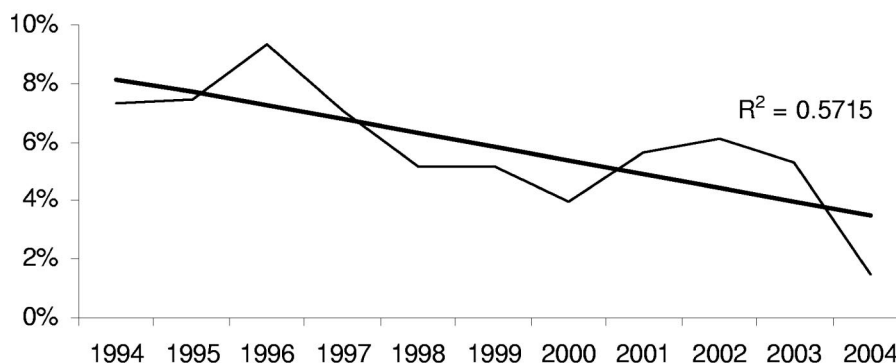


Figure 2. Percentage of asthma patients needing additional hospitalization each year.

95% confidence intervals (CIs), and yearly crude and direct adjusted incidence estimates for asthma hospitalization was performed using SAS statistical software, version 9.1 (SAS Institute Inc, Cary, NC).

RESULTS

Among the active-duty population, more than 85% were men, 68% were unmarried, 69% were white, and 41% were between 17 and 22 years of age at entry into the observation period (Table 1). Officers represented 9%, combat specialists represented 28%, and the largest service branch, the US Army, represented 37% of all personnel. Univariate analyses suggested significant associations among all demographic and occupational variables and asthma hospitalization. Although women represented only 14% of the total population, more than 24% of asthma hospitalizations were attributed to women. Additionally, the US Army, which contributed 37% of the total population, accounted for 49% of asthma hospitalizations. Health care workers constituted 4% of the population and 8% of hospitalizations for asthma (Table 1).

Among all active-duty military forces, the annual counts of first hospitalizations for all types of asthma declined from 22.3 per 100,000 persons to 12.6 per 100,000 persons between 1994 and 2004, resulting in an average annual decrease of 5.1% (Fig 1). Allowing multiple encounters per person, subsequent hospitalizations as a proportion of all asthma hospitalizations declined from 7.3% in 1994 to 1.5% in 2004, resulting in an average annual decrease of 0.5% (Fig 2).

The Cox regression analysis estimated HRs for all variables in the model while simultaneously adjusting for all other variables (Table 2). Women were at a significantly higher risk of hospitalization for asthma when compared with men (HR, 1.99; 95% CI, 1.80–2.17). Risk of hospitalization increased with an individual's age, with the oldest age group (35–65 years old) estimated to be at 1.66 (95% CI, 1.47–1.87) times the risk of the youngest group (17–22 years old). Black, Hispanic, or persons of other race/ethnicity were at significantly higher risk than white persons. US Army personnel were at a significantly higher risk relative to the other services (Fig 3). Officers were at a significantly lower risk of hospitalization for asthma when compared with enlisted pay grades (HR, 0.54; 95% CI, 0.46–0.63). Of the occupational categories considered, service and supply handlers (HR, 1.15; 95% CI, 1.00–1.31) and health care workers (HR, 1.44; 95% CI, 1.24–1.67) were at a small but significantly higher adjusted risk when compared with the largest occupational category, combat specialists (Fig 4).

DISCUSSION

A trend of declining rates of first hospitalization was identified during the study period for all services, mirroring declines in asthma hospitalization rates in the civilian population during a similar period.^{2,16,33,34} In addition, rates of subsequent hospitalization declined during the same period, possibly as a result of better asthma management strategies

Table 2. Cox Regression Estimates of Adjusted Hazard Ratios for Asthma Hospitalization in the US Military, 1994–2004

Characteristics	Hazard ratio (95% confidence interval)
Sex	
Men	1.00
Women	1.99 (1.82–2.17)
Marital status	
Single	1.00
Married	1.29 (1.18–1.41)
Age group, y	
17–22	1.00
23–28	0.64 (0.58–0.71)
29–34	0.90 (0.79–1.02)
35–65	1.66 (1.47–1.87)
Branch of service	
US Army	1.00
US Navy	0.73 (0.67–0.80)
US Air Force	0.62 (0.55–0.69)
US Marines	0.57 (0.50–0.66)
Race/ethnicity	
White	1.00
Black	1.87 (1.72–2.03)
Hispanic	1.29 (1.11–1.49)
Other	1.41 (1.21–1.64)
Home of record	
Northwest	1.00
Northeast	0.92 (0.83–1.01)
Southeast	0.88 (0.77–1.00)
Southwest	0.98 (0.89–1.08)
Non-United States	1.06 (0.93–1.21)
Pay grade	
Enlisted	1.00
Officer	0.54 (0.46–0.63)
Occupational status	
Combat specialists	1.00
Electronic repair	0.97 (0.82–1.15)
Communications and intelligence	1.05 (0.92–1.21)
Health care	1.44 (1.24–1.67)
Other technical and allied specialists	0.95 (0.73–1.24)
Functional support and administration	1.14 (1.01–1.27)
Electrical/mechanical equipment repair	0.99 (0.87–1.12)
Crafts workers	0.88 (0.69–1.13)
Service and supply	1.15 (1.00–1.31)
Trainees, other	1.10 (0.93–1.29)

using newly available pharmaceuticals; this trend has also been seen in other studies.³⁵

We identified several demographic factors associated with asthma. The significantly increased risk of asthma hospitalization observed in married personnel may be the result of spouses encouraging medical care. Marital status has been shown to be predictive of hospitalizations for a variety of diagnostic categories in prior studies of the active-duty population.^{11,12} The increased risk of hospitalization found in black and female personnel mirrors findings in similar stud-



Figure 3. Estimated risk of new hospitalization for each service branch as a function of time from start of active duty. Note that the differences observed might reflect different policies for hospitalization among the services rather than differences in absolute burden of asthma.

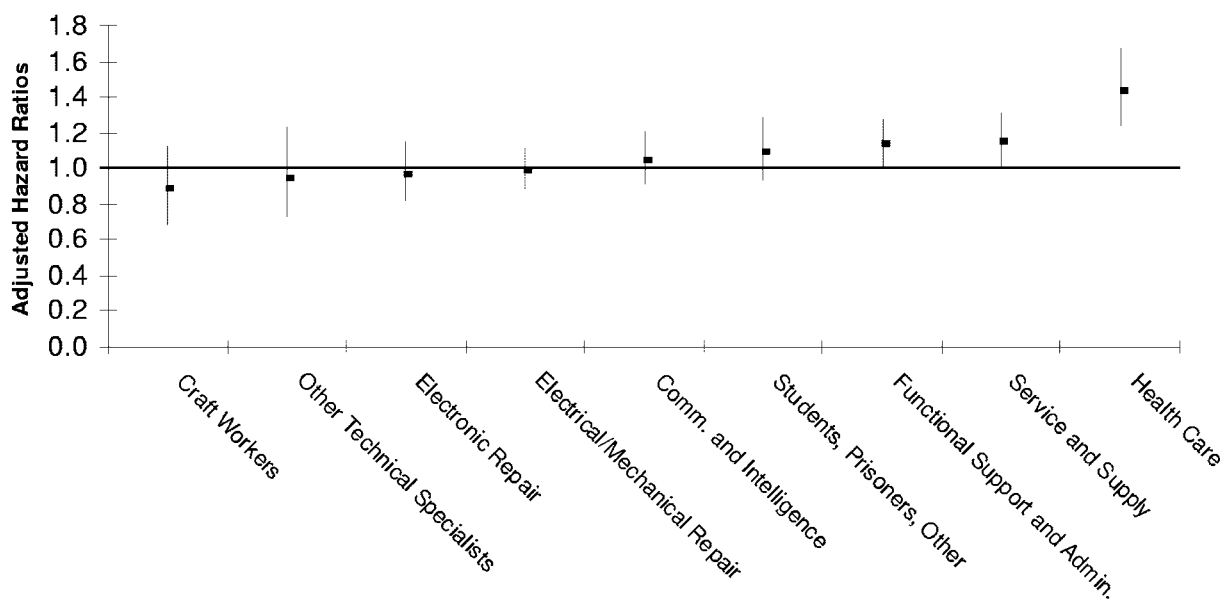


Figure 4. Estimated hazard ratios for active-duty occupational categories, with combat specialists used as reference.

ies.^{25,27,28,31,36,37} The increased risk observed in the oldest age category may be an effect of aging and mirrors the findings of another study of asthma in the active-duty population.³⁸

Military-specific factors were also associated with asthma. Risk of hospitalization was highest for the US Army, which also had the highest rate of hospitalization of all branches of service. It is possible that US Army personnel may be more frequently exposed to environmental triggers of asthma, such as airborne particulates, than other service branches³⁹ or that

these data may represent different thresholds or practices for hospitalization among the services. It is notable that the US Marine Corps would be expected to have similar occupational exposures, yet different techniques for identification and exclusion of asthmatic individuals before entry into the US Marine Corps may contribute to their lower estimated risks and rates of hospitalization in relation to the US Army. The decreased risk of hospitalization observed in officers, even after adjusting for marital status and age, may be the result of

better application of entrance standards, in contrast to the enlisted population. The trend of lower health care use among officers has been observed in other military research and may reflect a general perception of needing to appear healthy for promotional opportunities.^{11,12,40}

Perhaps the most important finding was the lack of risk associated with certain occupations, such as combat and craft workers. Although specific exposures to hazards such as dust, paints, and fumes could not be evaluated, these findings would argue against any overall occupational risk within these military professions. The small but significant increased risk of hospitalization observed in health care workers may be related to some selection bias among those who pursue health care careers. Additionally, all military personnel, regardless of occupation, must meet minimum standards for physical fitness to retain active-duty status. Likewise, it is possible that combat specialists may represent a group with a healthy selection bias, and, if so, this would tend to dilute any true association between their exposures and asthma hospitalization.

The declining rates of initial and subsequent hospitalization during the study period suggest improvements in asthma management. During the study period, the widespread use of inhaled corticosteroids,⁴¹ more efficient drug delivery methods,⁴² and the use of new and more effective combinations of therapies⁴³ have resulted in improved management of asthma.⁴⁴ During the same period, some prescription-only treatments became available without prescription.^{45,46} Our results are consistent with findings in the civilian population, where pharmaceutical management of asthma has been shown to be effective enough for some hospitals to begin providing prescriptions free of charge, similar to the free medical care provided to active-duty personnel.⁴⁵⁻⁴⁸

Although more than 4 million individuals were examined in this study, the population included younger and predominately male active-duty personnel, limiting generalization to the US Army Reserve, National Guard, and civilian populations. Unlike civilian populations, all active-duty personnel must maintain minimum fitness standards, and potential risk factors such as obesity are less common.³⁸ Hospitalizations for asthma before inclusion in the study could be neither evaluated for personnel first joining active-duty status after 1994 nor used to restrict young service persons with preexisting asthma from inclusion in the study. Since asthma is disqualifying for military service and waivers are rarely issued, active-duty service personnel may be expected to have a low prevalence of chronic asthma at entrance into military service. By limiting the study to only hospitalized cases, trends in outpatient encounters and subclinical asthma were not examined. Although we were unable to discern which asthma hospitalizations may have been related to combat deployment, and deployers do not have the same access to outpatient care in the combat theater, all people who developed asthma necessitating hospitalization while on deployment would have been transferred to standing military hospitals and captured in the data we evaluated.⁴⁹ Lastly, other

factors that may influence severity of asthma and rates of hospitalization, such as a history of geographic or environmental risks, previous infection, smoking, or exposures such as childhood pet ownership, could not be evaluated in our analyses.^{38,50-54}

This study is the first, to our knowledge, to use electronic medical records to estimate risk factors and the burden of asthma among the entire active-duty US military. Electronic records provide consistent sampling and counting methods over time and across geographic areas. The Cox time-to-event modeling accounts for late entry and early withdrawal from the observation period, providing the largest sample size possible. The ability to electronically match hospitalization records with demographic information allows hazard estimates to be adjusted for multiple population characteristics.

The evaluation of incident asthma hospitalizations among the all-volunteer US active-duty population included more than 4 million individuals serving in a variety of occupational roles. A trend of declining rates of initial hospitalization and subsequent hospitalization was identified. Survival analysis indicated that adjusted HRs were significantly higher for women, black persons, US Army personnel, older persons, and, to a lesser extent, health care workers and married persons. The decline in overall rates may have been the result of better outpatient management strategies and the introduction of new pharmaceuticals, reducing the need for hospitalization during the study period. Additional research is necessary to identify specific exposures and risk factors that contribute to the exacerbation of asthma and to continue development of successful management strategies to further reduce asthma's burden.

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- Requests for reprints should be addressed to:*
Christian J. Hansen, BS
Department of Defense Center for Deployment Health Research
Naval Health Research Center
PO Box 85122
San Diego, CA 92186-5122
E-mail: Hansen@nhrc.navy.mil
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Study objectives: Acute asthma attacks strike unpredictably and may lead to hospitalization for otherwise healthy individuals. The burden of asthma hospitalization on the US health care system has greatly interested providers who may believe the prevalence of asthma is increasing. The objective of this study is to examine annual incidence of hospitalization and frequency of rehospitalization for asthma among all active-duty US military personnel between 1994 and 2004, and to determine demographic and occupational risk factors of asthma hospitalization within a generally healthy US population.

Design: Annual demographic and occupational data were combined with electronic hospitalization records for patients with a primary discharge diagnosis of asthma to allow adjustment of hazard ratios for differences in population characteristics. Using Cox proportional hazard modeling, the authors investigated demographic and occupational risk factors of asthma hospitalization.

Results: Gender, marital status, an occupation as either a health care specialist or service and supply handler, pay grade, branch of service, and age of personnel were important independent risk factors of asthma hospitalization. Throughout the study period, yearly rates of hospitalization declined from 22.3 per 100,000 persons to 12.6 per 100,000 persons between 1994 and 2004, potentially reflecting improved outpatient management strategies.

Conclusions: While these data have some limitations, they suggest that the burden of asthma hospitalizations in a large, healthy population of US military personnel has declined during the last decade.

15. SUBJECT TERMS

asthma, prevalence, incidence, military personnel

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