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STudy of Active Duty Military Personnel for Environmental Deployment Exposures: Pre- and Post-Deployment Spirometry (STAMPEDE II)

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BACKGROUND: There is significant concern about the respiratory health of deployed military service members given the reported airborne hazards in southwest Asia, which range from geologic dusts, burn pit emissions, chemical exposures, and increased rates of smoking. There has been no previous comparison of pre- and post-deployment lung function in these individuals. METHODS: Military personnel who deployed to southwest Asia in support of ongoing military operations were recruited from the Soldier Readiness Processing Center at Fort Hood, Texas, from 2011 to 2014. The participants were asked to complete a brief survey on their respiratory health and perform both spirometry and impulse oscillometry studies at baseline with repeated survey and testing after deployment. RESULTS: Of the 1,693 deployed personnel who completed baseline examinations, 843 (50%) completed post-deployment testing. Post-deployment values demonstrated no statistical or clinical change in spirometry, with an increase in mean ± SD FEV_1 (% predicted) from 95.2 ± 12.6 to 96.1 ± 12.4 ($P = .14$), increase in mean ± SD FVC (% predicted) from 95.9 ± 11.8 to 96.4 ± 11.9 ($P = .32$), and increase in mean ± SD FEV_1/FVC from 81.5 ± 5.9 to 81.8 ± 6.1 ($P = .29$). Impulse oscillometry values showed statistical improvement with reduction in resistance (at 5 Hz and 20 Hz) and reactance (at 5 Hz). The presence of pre-deployment obstruction, self-reported asthma, smoking history, or increased body mass index also did not change spirometry values after deployment. DISCUSSION: To our knowledge, this was the first prospective evaluation of deploying military by using spirometry as an indicator for the possible development of pulmonary disease related to environmental exposures. Pre-deployment testing with spirometry and impulse oscillometry was unable to detect any significant change. In those with abnormal spirometry pre-deployment or asthma history, there was also not identifiable change that indicated worsening lung function. CONCLUSIONS: Utilization of spirometry for the deploying military population had little benefit and did not identify individuals with lung disease after deployment. Routine use was not warranted before or after deployment in the absence of pulmonary symptoms. *Key words: military personnel; airborne particulate matter; exposure; impulse oscillometry; spirometry.* [Respir Care 0;0(0):1–•. © 0 Daedalus Enterprises]

Introduction

There is ongoing discussion regarding the effect of deployment on the respiratory health of military personnel who deploy to southwest Asia in support of operations Iraqi Freedom, Enduring Freedom, and New Dawn.[1] Deployed individuals may be exposed to significant levels of airborne particulate matter from geologic dusts, burn pit emissions, wasted munitions, or limited exposures related

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to sulfur mine fires or chemical weapons caches.[2] Current evidence for a causative association between these exposures and the development of chronic pulmonary disease is limited.[3–5] Our initial study, STAMPEDE I, evaluated 50 soldiers within 6 months for new-onset respiratory symptoms during deployment.[3] The 2010 Armed Forces Health Surveillance Center report[6] concluded, based on very limited evidence, that exposures to burn pit smoke did not seem to increase the risk for pulmonary complications. In 2011, the Institute of Medicine expressed concern about burn pit particulate matter exposures but conceded that there was inadequate evidence to link these exposures to respiratory disease.[7] The Navy Millennium Cohort Study and another study from the conflicts in southwest Asia demonstrated increases in deployment-related respiratory symptoms.[8,9] Despite increases in symptoms, epidemiologic studies have not shown increases in respiratory disease.[10]

A Department of Defense/Veterans Affairs working group convened in 2010 to begin investigations into post-deployment lung disease.[11] Recommendations from the initial meeting included pulmonary evaluation for individuals with chronic symptoms, abnormal pulmonary function testing, or reduced exercise tolerance. Assessment of the utility of pre- and post-deployment spirometry for all service members was also recommended to objectively assess deployment-related respiratory changes. However, Department of Defense representatives advocated conducting a clinical study before universal implementation of pre-deployment spirometry.[12] The initial pre-deployment data were reported in 2017 by our study group and found that the deploying soldiers were older and heavier, and frequently smoked, and may have had undiagnosed pre-deployment lung disease.[13] Abnormal spirometry was common (22.3%) but did not correlate with underlying disease based on medical history and symptoms. The pre-deployment data also showed that self-reported asthma, symptoms of wheezing, and slower 2-mile (3.2 km) run times on physical fitness testing were predictive of abnormal spirometry. This study provided post-deployment follow-up to assess for changes in pulmonary function based on pre-deployment risk factors and post-deployment symptoms.

QUICK LOOK

Current knowledge

To our knowledge, the role of pulmonary function testing in evaluating military personnel due to deployment-related exposures has not been previously studied. Although there are increases in respiratory symptoms, direct evidence for chronic respiratory disease caused by deployment is lacking. Identifying those individuals with evidence of disease is important to early recognition and treatment.

What this paper contributes to our knowledge

Screening with spirometry of all military personnel before and after deployment does not provide useful data on the presence or absence of underlying lung disease. Routine use is not warranted before or after deployment in the absence of known lung conditions or active pulmonary symptoms.

Methods

A prospective study was conducted that involved Army personnel who underwent deployment to southwest Asia (Iraq, Afghanistan, Kuwait, or Qatar) from 2011 to 2014 in support of ongoing combat operations. All study participants were recruited from Fort Hood, Texas, during their centralized pre-deployment processing. Any soldier with a pending deployment to southwest Asia was eligible for study participation; there were no specified exclusion criteria. The Brooke Army Medical Center Institutional Review Board approved the study design and implementation; all the participants completed a written informed consent process.

Before deployment, all the participants completed a questionnaire and underwent baseline chest radiography, spirometry, and impulse oscillometry. An identical post-deployment evaluation was conducted in those individuals who returned through the Fort Hood Soldier Readiness Processing Center, usually within 1 to 2 wk of re-deployment from southwest Asia. The pre-deployment questionnaire collected basic demographic, smoking, and deployment data. The participants reported their current medications, medical history, pulmonary symptoms (dyspnea, cough, wheezing, sputum production, and exercise intolerance) and performance on the Army Physical Fitness Test to include 2-mile (3.2 km) run times. The post-deployment questionnaire detailed deployment airborne ex-

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posures (dust and/or sand, vehicle exhaust, burning trash, and industrial fumes), smoking history, respiratory illnesses, and respiratory symptoms before, during, and after deployment.

The participants performed spirometry, conducted by the same respiratory therapist who did the pre-deployment evaluation by using a VMax spirometer (Vyaire Medical, Yorba Linda, California). They underwent a standard forced expiratory maneuver from maximal inhalation to maximal exhalation to record FEV_1, and FVC in accordance with the American Thoracic Society standards for spirometry quality and reproducibility. No post-bronchodilator assessments were obtained. Obstruction on spirometry was defined as FEV_1/FVC below the lower limit of normal as defined by the National Health and Nutrition Examination Survey III reference values.[14] Supranormal spirometry was defined as an FEV_1 or FVC > 110% predicted.[15] Impulse oscillometry was also conducted as part of the evaluation before and after deployment. Oscillatory resistance was obtained by using system software (MasterScreen IOS Impulse Oscillometry, Vyaire Medical, San Diego, California). Testing was performed according to published guidelines and measurements of resistance at 5 Hz (total respiratory resistance), resistance at 20 Hz (proximal resistance), and reactance at 5 Hz (distal capacitive reactance) were recorded.[16,17]

Mean ± SD was used as summary statistics for continuous variables, such as spirometry data, age, and body mass index (BMI). These variables were analyzed by using the Student *t* test and analysis of variance or the Wilcoxon test when appropriate. Categorical variables, such as risk factors during deployment, sex, and race, were summarized by using percentages and were analyzed by using chi-square tests or the Fisher exact test when appropriate. Significance for results was established when *P* values were <.05. Potential risk factors (smoking, presence of obstruction, increased BMI, or self-reported asthma) for spirometric obstruction during deployment and post-deployment symptoms (dyspnea, cough, wheezing, sputum production, and decreased exercise tolerance) were entered into a multivariable logistic regression model. Odds ratios, along with their corresponding 95% CIs were reported, along with the area under the curve for the model. All statistical analyses were performed by using SPSS v 22.0 (IBM, Armonk, New York).

Results

The original cohort consisted of 1,693 personnel who completed the pre-deployment evaluation; data from 843 participants were collected after southwest Asia deployment, from 2012 to 2014. This represented 50% of the original cohort reported previously.[13] Baseline demographics for the returning cohort are shown in Table 1. These personnel were predominantly deployed to Afghanistan for an average of 9.5 ± 1.3 months. There was no difference in baseline demographics in the returning cohort (age, sex, ethnicity, BMI, smoking history, or Army branch) from the original pre-deployment cohort. Nearly 30% of the participants were current or former smokers, and 74% of the soldiers were classified as overweight or obese based on BMI.

Table 1. Demographics of Pre-Deployment Vs Post-Deployment Cohorts

Demographic	Pre-Deployment Cohort	Post-Deployment Cohort
Age, mean ± SD y	32.2 ± 9.1	32.9 ± 9.2
Sex, *n* (%)		
Male	1,407 (83.1)	703 (83.4)
Female	286 (16.9)	140 (16.6)
Race, *n* (%)		
African-American	343 (20.2)	165 (19.6)
Asian	76 (4.5)	36 (4.3)
White	979 (57.8)	492 (58.4)
Hispanic	295 (17.4)	150 (17.8)
Body mass index, *n* (%)		
<25.0 kg/m^2	452 (26.7)	201 (23.8)
25.0–29.9 kg/m^2	903 (53.3)	465 (55.2)
>30.0 kg/m^2	338 (20.0)	177 (21.0)
Smoking, *n* (%)		
Never	1,106 (65.3)	591 (70.1)
Former	327 (19.3)	157 (18.6)
Current	253 (14.9)	95 (11.3)
Duty status, *n* (%)		
Active duty	706 (41.7)	245 (29.1)
National Guard	429 (25.3)	296 (35.1)
Reservist	516 (30.5)	290 (35.1)

The returning cohort noted frequent exposure to airborne hazards. Frequency of exposures were quantified by using a scale of 0, none; 1, occasionally; 2, regularly; and 3, continuously. The mean symptom score for Dust and/or sand exposure was the most common, at 1.97 ± 0.74, vehicle exhaust at 1.68 ± 0.76, burn pit smoke at 1.58 ± 0.83, and other fumes at 1.49 ± 0.86. The mean symptom score related to these exposures (0, none; 1, mild; 2, moderate; 3, severe) were quantified as less than mild for cough (0.26 ± 0.43), wheeze (0.08 ± 0.27), dyspnea (0.15 ± 0.35), decreased exercise tolerance (0.10 ± 0.30), and sputum production (0.09 ± 0.28). The overall frequency of respiratory symptoms during the deployment period is shown in Figure 1. Self-reported symptoms increased during deployment and returned closer to pre-deployment levels on return to the United States. Cough was the most frequently reported symptom but occurred on average fewer than two times weekly. There was no clinically or statistically significant increase in symptoms during deployment compared with reported pre-deployment levels.

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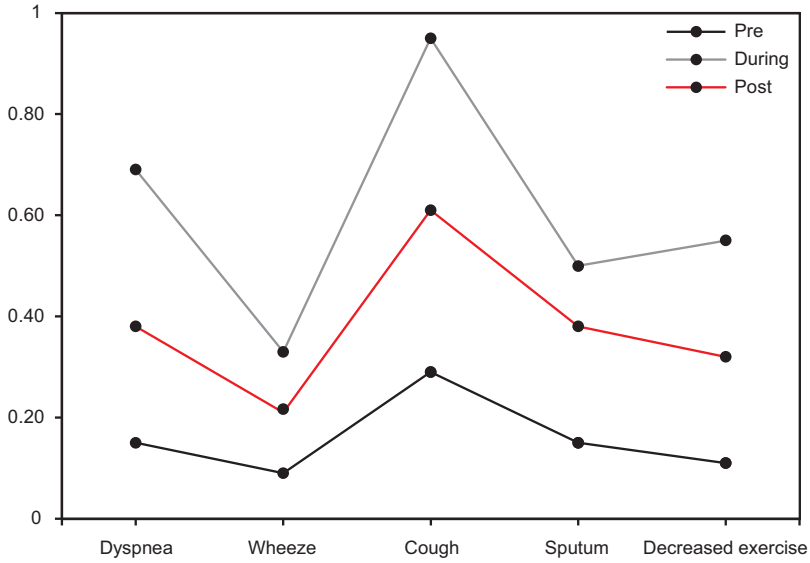

Fig. 1. Self-reported pulmonary symptoms. Self-reported respiratory symptoms before, during, and after deployment: 0, never; 1, <2 times weekly; 2, 2–5 times weekly; 3, daily.

Table 2. Pulmonary Function Testing: Pre- Vs Post-Deployment

Test	Pre-Deployment Cohort*	Pre-Deployment Cohort†	Post-Deployment Cohort	*P*‡
Spirometry				
Subjects, *n*	1,693	843	843	
FEV_1, mean ± SD % predicted	94.8 ± 12.7	95.2 ± 12.6	96.1 ± 12.4	.14
FVC, mean ± SD % predicted	95.5 ± 11.9	95.9 ± 11.8	96.4 ± 11.9	.32
FEV_1/FVC, mean ± SD %	81.7 ± 6.4	81.5 ± 5.9	81.8 ± 6.1	.29
$FEF_{25-75\%}$, mean ± SD % predicted	96.6 ± 25.9	96.5 ± 25.5	98.1 ± 25.9	.19
Supranormal, *n* (%)				
Subjects	245 (14.5)	129 (15.3)	158 (18.7)	
FVC, >110% predicted	190 (11.2)	101 (12.0)	114 (13.5)	NA
FEV_1, >110% predicted	180 (10.6)	97 (10.7)	116 (13.8)	NA
Impulse oscillometry				
Subjects, *n*	1,654	843	843	
Resistance at 5 Hz	4.39 ± 1.48	4.34 ± 1.47	4.12 ± 1.37	.002
Resistance at 20 Hz	3.53 ± 1.06	3.49 ± 1.08	3.33 ± 0.92	<.001
Reactance at 5 Hz	−1.49 ± 0.71	−1.48 ± 0.74	−1.37 ± 0.73	<.001

* All the subjects enrolled in the initial cohort.
† Subjects who completed the post-deployment evaluation.
‡ *P* values represent comparison of values between subjects (n = 843) with pre- and post-deployment evaluation.
$FEF_{25-75\%}$ = forced expiratory flow during the middle half of the FVC maneuver
NA = not applicable

Mean pre- and post-deployment spirometry data for the initial cohort and returning cohort are presented in Table 2. No statistical differences were noted between the overall and returning cohorts. For the returning cohort, there was a minimal nonsignificant increase in all post-deployment spirometry values (FEV_1, FVC, and FEV_1/FVC) compared with pre-deployment values. These values were not clinically important in terms of spirometry interpretation. A similar finding was noted with impulse oscillometry values, with significant decreases in resistance (resistance at 5 Hz and resistance at 20 Hz, and improvement in reactance (reactance at 5 Hz) values. There continued to be a percentage of soldiers (18.7%) with supranormal values, which increased slightly above pre-deployment findings (14.5%).

There were 116 individuals (19%) in the cohort identified with obstruction (FEV_1/FVC < LLN) based on National Health and Nutrition Examination Survey III refer-

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Table 3. Pulmonary Function Testing With Airway Obstruction ($FEV_1/FVC < LLN$)

Spirometry	Pre-Deployment Cohort (mean ± SD)	Post-Deployment Cohort (mean ± SD)	% Change (mean ± SD)	*P*
Obstruction (all) ($N = 116$)				
FEV_1, % predicted	85.4 ± 11.9	87.9 ± 13.2	4.0 ± 9.7	.02
FVC, % predicted	97.2 ± 12.9	99.0 ± 12.5	0.8 ± 8.2	.01
FEV_1/FVC, %	72.2 ± 5.4	73.2 ± 5.9	2.8 ± 5.9	.90
$FEF_{25-75\%}$, % predicted	63.8 ± 15.7	68.6 ± 19.0	9.0 ± 15.9	.01
Obstruction (pre-deployment) ($n = 33$)				
FEV_1, % predicted	84.1 ± 10.5	92.9 ± 10.5	8.8 ± 10.7	<.001
FVC, % predicted	97.2 ± 11.5	97.8 ± 9.5	0.6 ± 7.8	.68
FEV_1/FVC, %	71.5 ± 4.3	78.5 ± 4.2	6.9 ± 6.6	<.001
$FEF_{25-75\%}$, % predicted	62.2 ± 9.4	80.5 ± 17.7	18.3 ± 18.0	<.001
Obstruction (pre-, post-deployment) ($n = 54$)				
FEV_1, % predicted	83.8 ± 13.1	84.8 ± 14.1	1.1 ± 7.7	.31
FVC, % predicted	98.8 ± 13.1	99.7 ± 14.1	0.9 ± 8.6	.42
FEV_1/FVC, %	69.8 ± 4.1	70.0 ± 4.3	0.2 ± 3.6	.65
FEF_{25-75}, % predicted	58.0 ± 14.2	61.3 ± 16.0	3.3 ± 11.1	.02
Obstruction (post-deployment) ($n = 29$)				
FEV_1, % predicted	90.1 ± 10.3	86.8 ± 9.6	–3.3 ± 6.8	.02
FVC, % predicted	94.2 ± 13.8	101.0 ± 12.6	6.8 ± 12.7	.01
FEV_1/FVC, %	77.6 ± 4.6	69.7 ± 6.4	–7.9 ± 8.5	<.001
FEF_{25-75}, % predicted	76.6 ± 16.9	63.5 ± 13.7	–10.9 ± 18.2	.01

$FEF_{25-75\%}$ = forced expiratory flow during the middle half of the FVC maneuver

ence values (Table 3).[14] Eighty seven had obstruction before deployment; obstruction remained in 54 (47%) on post-deployment spirometry, and 33 (28%) normalized. An additional 29 individuals (25%) had normal pre-deployment spirometry and developed obstruction after deployment. Analysis of the overall cohort demonstrated no statistically significant change in spirometry values for those identified with obstruction. In those individuals with pre- and post-deployment obstruction, there was a small improvement in FEV_1, FVC, and FEV_1/FVC. Of the 29 subjects who developed obstructive indices, 13 (45%) had an FEV_1 of >90% predicted. Similar findings were noted in the pre-deployment obstructed (33%) and pre- and post-deployment obstructed (32%) groups.

Because cigarette smoking, self-reported asthma, and increased BMI may impact spirometry, subgroup analyses by these factors was performed (Table 4). All 3 groups demonstrated slight improvement in post-deployment spirometry compared with pre-deployment values. Age, asthma, obesity, smoking status, and sex were entered into a logistic regression model to predict obstruction after deployment. The results showed that only age and asthma were significantly predictive ($P = .02$ and .045, respectively). The odds ratios and their corresponding 95% CIs for the model are presented in Table 5. Even though there were statistically significant factors in the model, the area under the curve for the model was only 0.624, which indicated that it was poorly predictive. Further subgroup analysis of post-deployment symptoms identified only self-reported moderate wheezing correlated with post-deployment obstruction ($P = .026$) (Table 6).

Discussion

The respiratory effects from large-scale deployment of military forces to austere environments remain a concern to the United States military. In southwest Asia, since 2003, there have been nearly 3.5 million military personnel deployed in support of military operations. This theater of operations poses various airborne hazards, predominantly composed of geologic dusts with particulate matter of $<5\ \mu$ in size.[2] Other potential hazards include smoke from large burn pits, chemical munitions, urban air pollution, and sulfur mine fires. Neither the short- nor long-term effects on pulmonary health have been fully elucidated, but the potential detriment to lung function from airborne particulate matter remains.[1] This study evaluated whether pre-deployment spirometry and impulse oscillometry would identify service members at risk for lung function decline. Our results indicated that screening spirometry and impulse oscillometry before deployment did not predict post-deployment lung function abnormalities, and both modalities showed an overall slight improvement. However, moderate wheezing (>2 times weekly) was the single symptom that correlated with post-deployment obstruction.

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Table 4. Pulmonary Function Testing Based on Risk Factors

Spirometry	Pre-Deployment Cohort	Post-Deployment Cohort	% Change	*P*
Smoking				
Subjects, *n*	252	252		
FEV_1, mean ± SD % predicted	94.7 ± 11.7	96.7 ± 11.9	2.0	.053
FVC, mean ± SD % predicted	95.6 ± 11.2	97.3 ± 11.8	1.7	.08
FEV_1/FVC, mean ± SD %	81.3 ± 5.6	81.6 ± 6.0	0.3	.58
$FEF_{25-75\%}$, mean ± SD % predicted	95.7 ± 25.2	98.9 ± 25.3	3.3	.15
Asthma				
Subjects, *n*	39	39		
FEV_1, mean ± SD % predicted	92.3 ± 16.3	93.8 ± 17.2	1.4	.71
FVC, mean ± SD % predicted	96.5 ± 13.1	97.2 ± 14.6	0.7	.83
FEV_1/FVC, mean ± SD %	78.5 ± 8.3	79.2 ± 7.9	0.6	.73
$FEF_{25-75\%}$, mean ± SD % predicted	85.4 ± 31.0	87.9 ± 29.1	2.5	.71
Body mass index of 25–30 kg/m^2				
Subjects, *n*	474	474		
FEV_1, mean ± SD % predicted	95.1 ± 12.3	96.1 ± 12.2	0.7	.36
FVC, mean ± SD % predicted	95.8 ± 11.8	96.5 ± 11.7	1.0	.19
FEV_1/FVC, mean ± SD %	81.2 ± 5.7	81.5 ± 5.8	0.3	.43
$FEF_{25-75\%}$, mean ± SD % predicted	96.1 ± 25.4	97.7 ± 25.9	1.7	.34
Body mass index > 30 kg/m^2				
Subjects, *n*	168	168		
FEV_1, mean ± SD % predicted	94.0 ± 12.6	97.0 ± 13.3	3.1	.02
FVC, mean ± SD % predicted	93.9 ± 11.2	96.8 ± 12.3	3.0	.031
FEV_1/FVC, mean ± SD %	81.4 ± 2.3	81.7 ± 6.3	0.2	.82
$FEF_{25-75\%}$, mean ± SD % predicted	98.6 ± 27.1	102.7 ± 27.7	4.2	.16

$FEF_{25-75\%}$ = forced expiratory flow during the middle half of the FVC maneuver

Table 5. Logistic Regression Analysis for Obstruction

Term	Odds Ratio (95% CI)	*P*
Increased Age, y	1.03 (1.00–1.07)	.02
Asthma	2.50 (1.02–6.11)	.045
Obesity	1.30 (0.67–2.54)	.44
Smoking	1.29 (0.73–2.27)	.38
Male	1.75 (0.84–3.67)	.14

* $P < .05$ significant.

Table 6. Subgroup Analysis of Spirometry Based on Post-Deployment Symptoms

Symptom	Level	Results, mean ± SD	*P*, Wilcoxon Test
Dyspnea	Normal	1.37 ± 0.66	.37
	Obstruction	1.49 ± 0.80	
Wheezing	Normal	1.21 ± 0.55	.03
	Obstruction	1.41 ± 0.79	
Cough	Normal	1.65 ± 0.89	.74
	Obstruction	1.59 ± 0.83	
Sputum	Normal	1.38 ± 0.80	.73
	Obstruction	1.42 ± 0.86	
Exercise tolerance	Norm	1.33 ± 0.67	.25
	Obstruction	1.38 ± 0.65	

Our prospective evaluation of military personnel before and after deployment led to several important findings. Respiratory symptoms in the deployed population were commonplace, likely due to dust or air pollution exposures, but they generally decreased after deployment. The slight improvement in spirometry and impulse oscillometry values was not clinically important and highlighted the variability of spirometry. In addition, those individuals with baseline obstruction (10.3%) had a minimal change in their spirometry, and nearly one third normalized after deployment. Subgroup analyses of smoking (29.9%), increased BMI of > 30 kg/m^2 (19.9%), or a self-reported history of asthma (4.6%) did not demonstrate significant change in pre- and post-deployment spirometry. Most importantly, the 50% rate of individuals who repeated spirometry after deployment highlighted the difficulty of studying any population given the constraints of time, resources, and the geographic distribution of military personnel.

We first reported the data from this cohort of 1,693 participants based on the pre-deployment spirometry findings.[13] Notably, more than one third of surveyed solders

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had a smoking history; 73% were overweight or obese, with a BMI >25 kg/m^2; and 6.2% reported a history of asthma. Abnormal spirometry was found in 22.3% of the participants, with nearly one third who demonstrated supranormal obstruction. Those soldiers with abnormal spirometry compared to normal spirometry reported more asthma (10.1 vs 5.1%), failed physical fitness tests (9.0 vs 4.6%), and increased frequency of respiratory symptoms (32.8 vs 24.3%). Based on the pre-deployment findings, we expected to identify some change in the cohort after deployment. However, the participants with baseline obstruction, history of smoking, increased BMI, or self-reported asthma had no significant change in spirometry to warrant additional evaluation. Even the participants with baseline obstruction who remained obstructed (n = 54) only had a minimal 0.2% change in FEV_1/FVC. This indicated that, despite the potential airborne particulate matter, these participants may not have had underlying inflammation and simply represented a normal variant because nearly one third had supranormal obstruction.

We recently confirmed the high number of individuals with abnormal spirometry in another military population. A study of 900 non-deployed military personnel identified nearly 11% had non-specific changes with a single spirometry.[18] Ninety-eight subjects were identified with abnormal spirometry, including 33 obstructive, 44 restrictive, 3 mixed, and 18 isolated flow-volume loop abnormalities. Historical features (smoking, exertional dyspnea, cough, asthma, or 2-mile (3.2 km) physical fitness test run failure) had no effect on the probability of an abnormal spirometry result (P = .56). Although physical fitness test failure probability is strongly affected by exertional dyspnea and current smoking, abnormal spirometry results did not have a statistically significant effect (P = .38).[18] Spirometry as a screening tool was poorly predictive for respiratory symptoms or decreased exercise tolerance in this non-deployed military cohort. Further evidence was provided by the current study for a deployed population.

An initial workshop at the 2011 Department of Defense/Veterans Affairs Airborne Hazards Conference[19] addressed the potential adoption of screening spirometry in military personnel. Four issues were raised as potential barriers to implementation: cost, reliability, the conduct of pre- and post-deployment spirometry, and use of spirometry in the military population to detect new pulmonary disease.[19] The United States Army Public Health Command provided an in-depth analysis for a single spirometry examination and projected start-up costs alone to be nearly $35 million. Primary issues in periodic spirometry evaluation are to establish good baseline measurement, maintain quality and within-person reproducibility, and identify individuals with excessive lung function decline.[20] Ensuring consistent quality data would be a challenge given the widespread distribution of military personnel. Based on current epidemiologic data, the proportion of military personnel who develop pulmonary disease related to deployment is limited; as suggested, there would be no benefit in obtaining baseline spirometry for the vast majority of military personnel who never develop pulmonary disease.[10]

Both asthma and airway hyperreactivity are common in military personnel with respiratory symptoms.[21] These conditions no longer automatically disqualify individuals from military service, and personnel may remain on active duty with well-controlled disease. It has been postulated that extreme southwest Asia climate conditions, geologic dust, and burn pit smoke exposures may worsen asthma control and increase exacerbations. Roop et al[22] surveyed deploying Army personnel and identified 5% of troops with a pre-deployment diagnosis of asthma. Both those with asthma and those without asthma had increased respiratory symptoms during deployment, whereas those with asthma reported poor symptom control while in theater.

A single-center review of 6,000 Veterans Affairs medical records (*International Classification of Diseases, 9th Revision* diagnostic codes, with minimum pulmonary function testing data) noted higher rates of "new onset" asthma in deployed personnel from 2004 to 2007 compared with never-deployed personnel (6.6 vs 4.3%).[4] This study did not address any asthma symptoms or related conditions that existed before deployment when assuming that the findings were all "new-onset asthma." Delvecchio et al[5] conducted an in-depth medical record review of 400 active duty military personnel diagnosed with asthma who were undergoing a medical fitness for duty evaluation due to persistent asthma symptoms. Fifty percent had never deployed, 25% were diagnosed before deployment, whereas 25% of the those with asthma were diagnosed after deployment.[5] There were no differences in pulmonary function tests or asthma severity based on the time of diagnosis or deployment history.[5]

The utility of spirometry would be in a population with a higher rate of respiratory disease such as recommended for specific occupational exposures. However, both the epidemiologic and clinical data from southwest Asia deployments since 2013 have not demonstrated increases in lung disease. The United States Army Public Health Command evaluated trends in rates of chronic lung diseases in the military population from 2001 through 2013.[10] Over the 13-y study period, rates of asthma and chronic bronchitis steadily decreased, whereas an increase in nonspecific bronchitis drove an overall increase in chronic respiratory disease.[10] More focused evaluations of other disease processes, such as COPD and sarcoidosis, have also failed to demonstrated increases in diagnostic rates related to deployment.[23,24] Two prospective studies of returning military personnel primarily identified asthma and non-spe-

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cific airway hyperreactivity as the primary respiratory disorder in their study populations.[3,25] Longer deployments were associated with increased bronchodilator responsiveness, with a trend toward increased air-flow limitation.[25]

As part of the 2011 Department of Defense/Veterans Affairs Airborne Hazards workshop on spirometry, the following recommendation was made by Department of Defense representatives and have been confirmed by this study: "Department of Defense policy at present should not require routine surveillance spirometry in all military personnel. The burden of evaluating asymptomatic personnel with pulmonary function testing abnormalities would outweigh any benefit from early disease detection. No such recommendations exist for asthma and COPD screening for the general population and the incidence of other chronic lung diseases is extremely small."[12]

Conclusions

Implementation of pre- and post-deployment spirometry would have significant logistic implications given the numbers (>3.5 million personnel deployed), numerous military bases throughout the world, and quality data that could be obtained. Furthermore, there is no current system in the military electronic medical record to do serial tracking as is done in occupational surveillance. This study compared pre- and post-deployment pulmonary function testing in the general military population and showed a slight overall improvement in both spirometry and impulse oscillometry values, despite reported increases in respiratory symptoms. Further analysis of individuals with baseline obstruction or with risk factors, such as asthma, smoking, or increased BMI, also noted no significant changes. The use of routine spirometry to screen the re-deploying population for deployment-related lung disease was not shown to be beneficial. Spirometry in the military population would be most helpful in deployed individuals with persistent respiratory symptoms (specifically wheezing) as currently recommended by guidelines for the general population.

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