Assessment of Deployment-Related Exposures on Risk of Incident Mental Health Diagnoses Among Air Force Medical Service Personnel: Nested Case–Control Study

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ABSTRACT Background: Recent military conflicts in Iraq (Operation Iraqi Freedom), Afghanistan (Operation Enduring Freedom), and elsewhere have been associated with psychological impacts among military personnel. However, relatively little is known about the relationship between those conflicts and psychological health of military health care professionals. Previous work has shown certain demographic factors associated with diagnosed mental health conditions after deployment. However, unique exposures in the deployed environment may be present that are also associated. Understanding the relationship between the demographic factors, exposures, and post-deployment mental health (PDMH) conditions has not been investigated. The purpose of this study was to determine the association between occupational and/or environmental exposures and incident PDMH conditions in a defined population of United States Air Force health care personnel returning from the deployed environment (i.e., deployment-related exposures). Methods: A nested case–control study compared cohort members with ($N = 4{,}114$) and without ($N = 14{,}073$) a PDMH condition in terms of deployment-related occupational and/or environmental exposures. PDMH conditions were identified using the electronic health record and exposures were determined using post-deployment health assessments. Demographic-adjusted multivariable logistic regression models were used to compute odds ratios (ORs). Results: The final regression model comprised five exposure and 12 demographic variables. Reported exposures were not strongly associated with incident PDMH conditions (OR ranged from 1.22 to 1.38) and were lower than some demographic factors. Demographic characteristics with relatively large effect sizes (ORs less than 0.5 or greater than 1.5) included the protective factors of Air Force Guardsman (OR: 0.45), reservists (OR: 0.34), and surgeons (OR: 0.32), as well as the risk factor of nurses (OR: 1.51). All model parameters had a p-value less than 0.0001 and the area under the receiver operating characteristic curve was 0.668. Conclusions: Given the low area under the receiver operating characteristic, the final statistical model had only marginal performance in its ability to correctly identify cases. Thus, other factors should be studied to identify additional predictors for PDMH conditions.

INTRODUCTION

Although recent military conflicts in Iraq (Operation Iraqi Freedom), Afghanistan (Operation Enduring Freedom), and elsewhere have been associated with adverse post-exposure psychological impacts in military personnel,[1–3] there has been relatively little information addressing the impact on military health care professionals.[4–8] Given this observation, a study was conducted[8] to ascertain whether Critical Care Air Transport Team (CCATT) members were at increased risk for incident post-deployment mental health (PDMH) conditions. The authors found that there was no additional relative risk for psychological effects that could be attributed to the CCATT work environment *per se* versus exposure to the deployed health care environment. It was observed, however, that both the CCATT members and the control group, the latter comprising job-matched United States Air Force (USAF) health care professionals with at least one deployment but no CCATT experience, had a burden of mental health conditions that was on par with that of the larger population of military personnel serving in combat-specific occupations. A subsequent single-cohort analysis of the entire population of United States Air Force Medical Service (AFMS) personnel returning from the deployment environment replicated this observation.

Although these demographic findings were helpful, it was hypothesized that perhaps unique exposures were present down-range that might be associated with PDMH conditions. Thus, a follow-on nested case–control study was conducted using available post-deployment health assessment (PDHA) Department of Defense Form 2796 (DD 2796) questionnaire data to ascertain the risk for occupational/environment exposures in those AFMS personnel with incident PDMH conditions in comparison with those without such a diagnosis. Thus, the purpose of this study was to determine the association (i.e., odds ratios [OR]) between occupational and/or environmental exposures and incident PDMH conditions in a defined population of AFMS personnel returning from the deployed environment (i.e., deployment-related exposures).

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METHODS

Study Design

This nested case–control study compared self-reported deployment-related occupational and/or environmental exposures in a previously assembled cohort of AFMS personnel who were originally assessed for the outcome of an incident PDMH condition based on review of electronic health record (EHR) data. In this case–control study, subjects were categorized by the presence or absence of a PDMH condition; exposures were identified from PDHAs. The study was conducted under a human-use protocol approved by the 711th Human Performance Wing Institutional Review Board and in accordance with Federal and USAF regulations on the protection of human subjects in biomedical and behavioral research.

Subjects

Inclusion Criteria

The previous cohort was assembled by utilizing Air Force Personnel Center (AFPC) data to define the population of AFMS personnel who were on active duty, Air National Guard, or Air Force Reserve status between 2003 and 2013 (inclusive). AFMS personnel were defined as those having an Air Force Specialty Code (AFSC) that began with the number 4 (N = 117,844). Some subjects cross-trained either into or out of a medical AFSC during the study period. Subjects who completed at least one deployment (data also from AFPC) when they carried a medical AFSC were included in the cohort (N = 32,354) (see Fig. 1).

Exclusion Criteria

Military Health System (MHS) data, which include medical encounters from military medical treatment facilities and civilian network providers (including both out- and in-patient care), were used to ascertain whether members had a diagnosis of a mental health condition before deployment. A mental health condition was defined as an International Classification of Diseases, 9th Revision (ICD-9) code between 290 and 319 (inclusive), excluding 305.1 for tobacco use disorder.

A single mental health diagnosis was sufficient to exclude a service member as having a preexisting mental health condition (N = 7,067); the threshold to screen service members out of the study cohort was set low, i.e., no confirmatory diagnosis was required. Service members for whom MHS data were not available were excluded (N = 878). Thus, the original cohort study comprised 24,409 subjects. For this nested case–control study, subjects who did not have at least one completed PDHA DD 2796 questionnaire were also excluded (N = 5,247). In addition, those whose only PDHA occurred after they were censored, defined as the time of the diagnosis of an incident PDMH condition or the time of last available medical data, were excluded from the study (N = 975). The final study population comprised 18,187 subjects (Fig. 1).

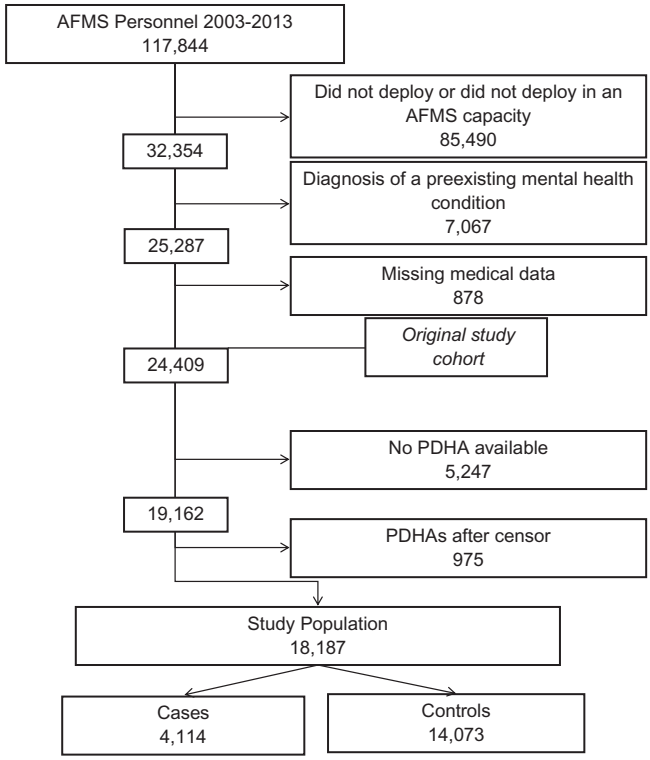

FIGURE 1. Subject study eligibility flow diagram.

Analysis of Missing Data

Starting with the original study cohort (N = 24,409) and removing the 975 subjects without a valid PDHA, the 5,172 cases and 18,262 controls were compared on the basis of the proportion missing a DD 2796 questionnaire. Of these 23,434 subjects, 20.46% of cases (1,058 people) and 22.94% (4,189 people) of controls were missing a questionnaire; this difference was statistically significant (χ_1^2 = 14.289, p = 0.0002) with controls having slightly more exclusions than cases. Based on multivariable logistic regression, the following demographic factors were associated with an increased likelihood of absence of a DD 2796 questionnaire: dentist (OR: 2.76; 95% confidence interval [CI]: 2.16, 3.52) or ophthalmic technician (OR: 2.86; 95% CI: 1.97, 4.13) career field; female gender (OR: 1.16, 95% CI: 1.08, 1.24); and deployment to Germany (OR: 9.54, 95% CI: 8.55, 10.65), the United States (OR: 6.62, 95% CI: 5.91, 7.41), or other country (OR: 4.98, 95% CI: 4.61, 5.38). All model parameters had a p-value less than 0.001 and the area under the receiver operating characteristic (AUROC) curve measuring the accuracy of the model predicting the response was 0.729.

Measurements

Outcome

Subjects were categorized by the presence or absence of a PDMH condition. To determine this, dates of deployment between 2003 and 2013 (inclusive) for the study population were obtained from AFPC records. Deployment data were

linked with medical records between 2003 and 2013 (inclusive) from the MHS data, which included encounter dates. Special care was taken to determine when the encounters occurred in relation to the deployment dates. As noted above, those who had at least one mental health diagnosis before the start of their first deployment were excluded from the study.

Subjects whose medical record contained an ICD-9 code on at least two separate occasions for a mental health diagnosis (i.e., 290–319, inclusive, excluding 305.1) after the start of their first deployment were classified as cases. The first diagnosis was considered a positive screen for a mental health condition and the second was considered a confirmatory test to improve specificity. The most common diagnosis categories were adjustment disorders, anxiety disorders (including post-traumatic stress disorder [PTSD]), and mood disorders. The total number of cases in the study was 4,114, or 22.62% of the study population.

Exposures

The PDHA DD 2796 questionnaire was developed to assess service members' state of health after deployment in support of military operations and to assist health care providers in identifying members with health care needs. It was developed and first distributed in April 2003 and was revised in January 2008 and again in September 2012. The DD 2796 questionnaire is administered to service members by a trained health care provider during in-theater medical out-processing or within 30 d after returning to home station.[9] This screening is used, in part, to identify possible deployment-related occupational and/or environmental exposures. Further information on the PDHA is available at http://www.pdhealth.mil/treatment-guidance/deployment-health-assessments.

DD 2976 questionnaire responses for cases and controls were obtained for the years 2003 through 2013, inclusive, from the Defense Health Agency Health Information Technology Division. Specific responses corresponding to deployment-related occupational and/or environmental exposures were extracted and linked to the dataset from the original cohort study. In addition to questions about specific occupational and/or environmental exposures, questions related to experiencing certain events (e.g., a blast or explosion) were also included in the analysis. Since the DD 2796 questionnaire had gone through several revisions, it was necessary to map the questions and responses for specific occupational and/or environmental exposures within each version of the questionnaire to a common set of corresponding dichotomous exposure variables (Table I). When a subject had more than one DD 2976 questionnaire available, a composite questionnaire was created in which a positive response to an item on any questionnaire was carried over as a positive response on the composite questionnaire. Special care was taken to ensure that exposures were identified before a subject was diagnosed with a PDMH condition. That is, questionnaires were only included in the composite questionnaire if they occurred before censure (i.e., time of diagnosis of an incident PDMH condition for cases or time of last available medical data for controls). Before the study investigators receiving the data, missing responses for individual DD 2976 questionnaire items were set as equivalent to a no exposure response, thus all 32 exposures investigated had complete data (i.e., exposure reported, else categorized as unexposed). Consequently, no sensitivity analysis could be performed to determine the effect of missing responses.

Covariates

The following demographic variables were available for every subject in the original study cohort: age (transformed into quartiles: ≤24, 25–30, 31–38, ≥39), career field (identified by AFSC; officers [aerospace medicine physician, biomedical clinician, biomedical specialist, dentist, health services administrator, medical commander, non-surgical/non-aerospace medicine physician, nurse, surgeon, and missing]; enlisted [aeromedical, aerospace and operational physiology, bioenvironmental engineering, cardiopulmonary laboratory, dental assistant, diagnostic imaging, diet therapy, health services management, medical laboratory, medical service, mental health services, ophthalmic, pharmacy, physical medicine, public health, and missing]), gender (male or female), location of first deployment (Afghanistan, Germany, Iraq, Kuwait, Qatar, United States, other, unknown/classified), marital status (divorced, single, married, other), rank (enlisted E1 through E9 or officer O1 through O6+), service component (active duty, Guard, or Reserve), total number of dependents (0, 1, 2, 3, ≥4), and total number of deployments (1 or ≥2). As constructed, career field was conditional on rank (i.e., individual AFSCs were specific to either enlisted or officer ranks). For those variables that could change over time (e.g., age), the values were ascertained at the start of each subject's first deployment.

Statistical Analysis

All the statistical analyses were performed with JMP Version 11 (SAS Institute Inc., Cary, NC) and IBM SPSS Modeler Version 14 (IBM, Armonk, NY). Contingency table analyses were used to compare outcome (i.e., a PDMH condition) response rates across levels within categorical demographic variables with three or more levels. Levels were then collapsed where no statistically significant inter-level differences were observed. The association of DD 2796 questionnaire items addressing occupational and/or environmental exposures with risk for incident PDMH conditions was assessed using demographic-adjusted multivariable logistic regression models. Demographic variables included age, career field conditional on rank (collapsed to six levels for officers: non-surgical physician [aerospace medicine physician and physician], nurse, officer group 1 [biomedical specialist, dentist, and health services administrator], officer group 2 [biomedical clinician and medical commander], surgeon, and missing; collapsed to six levels for enlisted: enlisted group 1 [aerospace and operational physiology, bioenvironmental engineering,

TABLE I. Mapping of DD 2796 Questionnaire Exposure Items by Version to Dichotomous Exposure Variable

DD 2796 Questionnaire Exposure Items[a]	Dichotomous Exposure Variable
• Did you see anyone wounded, killed, or dead during this deployment? [N, Y, Y-coalition, Y-enemy, Y-civilian] (2003) • Did you encounter dead bodies or see people killed or wounded during this deployment? [N, Y, Y-enemy, Y-coalition, Y-civilian] (2008) • Did you encounter dead bodies or see people killed or wounded during this deployment? [N, Y] (2012)	• Dead bodies or people killed/wounded
• Were you engaged in direct combat where you discharged your/a weapon? [N, Y, Y-land, Y-sea, Y-air] (2003, 2008) • Did you engage in direct combat where you discharged a weapon? [N, Y] (2012)	• Discharged a weapon
• During this deployment, did you ever feel that you were in great danger of being killed? [N, Y] (2003, 2008) • Did you ever feel like you were in great danger of being killed? [N, Y] (2012)	• Great danger of being killed
• During this deployment, did you experience any of the following events? [Blast or explosion, Vehicular accident/Crash, Fragment wound or bullet wound above your shoulders, Fall, Other event] (2008) • During this deployment, did any of the following events happen to you? [Blast or explosion, Vehicular accident/Crash, Fragment wound or bullet wound (head or neck), Other event] (2012)	• Blast/explosion • Vehicular accident/crash • Fragment/bullet wound (above shoulder) • Fall/other event
• While you were deployed, were you exposed to: environmental pesticides (like area fogging), smoke from oil fire, smoke from burning trash or feces, vehicle or truck exhaust fumes, tent heater smoke, JP8 or other fuels, fog oils (smoke screen), solvers, paints, ionizing radiation, radar/microwaves, lasers, loud noises, excessive vibration, industrial pollution, sand/dust, depleted uranium, other exposures? [No, Sometimes, Often] (2003) • Are you worried about your health because you were exposed to: depleted uranium, excessive vibration, fog oils (smoke screen), industrial pollution, ionizing radiation, JP8 or other fuels, lasers, loud noises, paints, pesticides, radar/microwaves, sand/dust, smoke from burning trash or feces, smoke from oil fire, solvents, tent heater smoke, vehicle or truck exhaust fumes, other exposures to toxic chemicals or materials? [N, Y] (2008) • Are you worried about your health because you believe you were exposed to something in the environment while deployed? [N, Y] (2012) • Healthcare provider then clarifies the deployer's exposure concerns from the following list: depleted uranium, excessive vibration, fog oils (smoke screen), industrial pollution, ionizing radiation, JP8 or other fuels, lasers, loud noises, paints, pesticides, radar/microwaves, sand/dust, smoke from burning trash or feces, smoke from oil fire, solvents, tent heater smoke, vehicle or truck exhaust fumes, other exposures to toxic chemicals or materials.	• Depleted uranium • Excessive vibration • Fog oils (smoke screens) • Industrial pollution • Ionizing radiation • JP8 or other fuels • Lasers • Loud noises • Paints • Pesticides (environmental) • Radar/microwaves • Sand/dust • Smoke from burning trash or feces • Smoke from oil fire • Smoke from tent heater • Solvents • Vehicle or truck exhaust fumes • Other exposure to toxic chemicals *(For the 2003 questionnaire, "sometimes" and "often" were reclassified as "yes")*

(continued)

TABLE I. Continued

DD 2796 Questionnaire Exposure Items[a]	Dichotomous Exposure Variable
• While you were deployed, were you exposed to: DEET insect repellant applied to skin, pesticide-treated uniforms? [N, Y] (2003) • Force Health Protection Measures: Please indicate which of the following items you used during this deployment and how often you used them. • DEET insect repellant applied to skin • Pesticide-treated uniforms [Daily, Most days, Some days, Never, Not available, Not required] (2008)	• DEET insect repellant • Pesticide-treated uniforms *(For the 2008 questionnaire, "daily," "most days," and "some days" were reclassified as "yes;" "never," "not available," and "not required" were reclassified as "no.")*
• How many days did you wear your MOPP overgarments? [free response] (2003) • Force Health Protection Measures: Please indicate which of the following items you used during this deployment and how often you used them. • MOPP overgarments [Daily, Most days, Some days, Never, Not available, Not required] (2008)	• MOPP overgarments *(For the 2003 questionnaire, 0 days was reclassified as "no" and ≥1 was reclassified as "yes." For the 2008 questionnaire, "daily," "most days," and "some days" were reclassified as "yes;" "never," "not available," and "not required" were reclassified as "no.")*
• How many times did you put on your gas mask because of alerts and NOT because of exercises? [free response] (2003) • Force Health Protection Measures: Please indicate which of the following items you used during this deployment and how often you used them. • NBC gas mask [Daily, Most days, Some days, Never, Not available, Not required] (2008)	• Gas mask *(For the 2003 questionnaire, 0 days was reclassified as "no" and ≥1 was reclassified as "yes." For the 2008 questionnaire, "daily," "most days," and "some days" were reclassified as "yes;" "never," "not available," and "not required" were reclassified as "no.")*
• Were you in or did you enter or closely inspect any destroyed military vehicles? [N, Y] (2003) • Did you enter or closely inspect any destroyed military vehicles? [N, Y] (2008) • Were you in a vehicle hit by a depleted uranium (DU) round, inside a destroyed vehicle that contained DU, or closely inspected such a vehicle? [N, Y, don't know] (2012)	• Destroyed military vehicles *(For the 2012 questionnaire, "don't know" was reclassified as "no.")*
• Do you think you were exposed to any chemical, biological, or radiological warfare agents during this deployment? [N, Y, don't know] (2003, 2008) • Do you think you were exposed to any chemical, biological, or radiological warfare agents during this deployment? [N, Y] (2012)	• Chemical, biological, radiological agents *(For the 2003 and 2008 questionnaires, "don't know" was reclassified as "no.")*
• Did you take any of the following medications during this deployment? [Anti-malaria pills] (2003) • Were you told to take medicines to prevent malaria? [N, Y] (2008, 2012)	• Anti-malaria medication

[a]Brackets contain relevant possible questionnaire responses.

dental assistant, and diagnostic imaging], enlisted group 2 [cardiopulmonary laboratory, diet therapy, health services management, medical laboratory, ophthalmic, physical medicine, and public health], enlisted group 3 [aeromedical and pharmacy], medical service, mental health services, and missing), gender, location of first deployment, marital status, rank (collapsed to two levels: enlisted or officer), service component, total number of dependents (collapsed to two levels: 0 or ≥1), and total

number of deployments. The threshold for statistical significance was set *a priori* at $p = 0.001$ given this study's large *N*.

RESULTS

Case and Control Groups

The demographic characteristics of the study population ($N = 18,187$), which included 4,114 cases (22.62%) and 14,073 controls (77.38%), are summarized in Table II. Cases differed from controls in the proportional distribution of officer and enlisted career fields, age, gender, marital status, service component, total deployments, and location of first deployment.

Exposure Analysis

Data were evaluated on the exposures (i.e., potential risk factors) self-reported by subjects on the DD 2796 questionnaire. In total, 25,170 questionnaires were identified for the 18,187 subjects, or approximately 1.4 questionnaires per person. Of these questionnaires, 10,902 (43.31%) were the 2003 version, 12,496 (49.65%) were the 2008 version, and 1,772 (7.04%) were the 2012 version. Table III summarizes reported exposures for cases and controls, stratified based on the DD 2796 questionnaire versions that ascertained the exposures. Results were stratified as all three versions of the questionnaires did not contain all of the questions of interest. For those exposures that were common to all DD 2796 questionnaire versions, cases reported more frequent exposures than controls for all exposures with the exception of anti-malaria medication. There were four exposures that were ascertained only on the 2003 and 2008 versions of the DD 2796 questionnaire. For those exposures, cases reported more frequent exposures than controls to N,N-diethyl-meta-toluamide (DEET) insect repellent, Mission-Oriented Protective Posture (MOPP) overgarments, and pesticide-treated uniforms. There were also four exposures that were ascertained only on the 2008 and 2012 versions of the DD 2796 questionnaire, for which cases reported more frequent exposures than controls.

As there were exposures that were not common to all three DD 2796 questionnaires, the logistic regression analysis was stratified based on questionnaire version. Exposure indicator variables (i.e., binary variables indicating whether an exposure was reported versus the absence of an exposure was reported) and variables corresponding to the demographic characteristics shown in Table II were included in each model, which were fitted using stepwise logistic regression. It was observed that only exposures that were common to all DD 2796 questionnaire versions were retained in the three final fitted models. Accordingly, a single logistic regression model was fitted to the data pooled from all three questionnaire versions but excluding those exposures that were not common to all questionnaire versions. The results of the final fitted multivariable logistic regression analysis (Table IV) revealed five exposures and 12 demographic characteristics that were significantly associated with having a PDMH condition. All model parameters

TABLE II. Demographic Characteristics of Cases and Controls

Characteristic	Cases		Controls		p-Value[a]
	N	%	*N*	%	
	4114	22.62	14,073	77.38	
Rank					
Officer	1270	30.87	5744	40.82	<0.0001
Enlisted	2844	69.13	8329	59.18	
Career field – Officer					
Non-surgical physician	206	16.22	1460	25.42	<0.0001
Nurse	634	49.92	1982	34.51	<0.0001
Officer group 1[b]	255	20.08	1201	20.91	0.5092
Officer group 2[c]	129	10.16	529	9.21	0.2944
Surgeon	46	3.62	565	9.84	<0.0001
Missing	0	0.00	7	0.12	NA
Career field – Enlisted					
Enlisted group 1[d]	326	11.46	1237	14.85	<0.0001
Enlisted group 2[d]	943	33.16	2897	34.78	0.1153
Enlisted group 3[f]	94	3.31	216	2.59	0.0460
Medical services	1375	48.35	3807	45.71	0.0148
Mental health services	106	3.73	171	2.05	<0.0001
Missing	0	0.00	1	0.01	NA
Service component					
Active duty	3641	88.50	11,089	78.80	<0.0001
Air National Guard	284	6.90	1,642	11.67	<0.0001
Air Force Reserve	189	4.59	1,342	9.54	<0.0001
Gender					
Male	2364	57.46	8914	63.34	<0.0001
Female	1750	42.54	5159	36.66	
Age (yr)					
≤24	1107	26.91	3455	24.55	0.0022
25–30	964	23.43	3352	23.82	0.6083
31–38	1138	27.66	3903	27.73	0.9274
≥39	905	22.00	3363	23.90	0.0115
Marital status					
Single	1257	30.55	4786	34.01	<0.0001
Married	2462	59.84	8242	58.57	0.1427
Divorced	390	9.48	1015	7.21	<0.0001
Other/missing	5	0.12	30	0.21	0.2381
Total dependents					
0	1833	44.56	6366	45.24	0.4404
1 or more	2281	55.44	7707	54.76	
Total deployments					
1	2630	63.93	8053	57.22	<0.0001
2 or more	1484	36.07	6020	42.78	
Deployment location					
Afghanistan	855	20.78	3310	23.52	0.0002
Germany	153	3.72	587	4.17	0.1967
Iraq	1474	35.83	4170	29.63	<0.0001
Kuwait	241	5.86	870	6.18	0.4453
Qatar	412	10.01	1681	11.94	0.0006
United States	158	3.84	671	4.77	0.0121
Other	646	15.70	2321	16.49	0.2276
Unknown/classified	175	4.25	463	3.29	0.0031

[a]Pearson χ^2.
[b]Officer group 1: biomedical specialist, dentist, and health services administrator.
[c]Officer group 2: biomedical clinician and medical commander.
[d]Enlisted group 1: aerospace and operational physiology, bioenvironmental engineering, dental assistant, and diagnostic imaging.
[e]Enlisted group 2: cardiopulmonary laboratory, diet therapy, health services management, medical laboratory, ophthalmic, physical medicine, and public health.
[f]Enlisted group 3: aeromedical and pharmacy.

TABLE III. Exposure Characteristics of Cases and Controls

Exposure	Cases	Controls	*p*-Value[a]
2003, 2008, and 2012 Questionnaires (*N*)[b]	4,114 (22.62%)	14,073 (77.38%)	
Anti-malaria medication	1,527 (37.12%)	5,814 (41.31%)	<0.0001
Chemical, biological, and radiological agents	42 (1.02%)	106 (0.75%)	0.0927
Dead bodies or people killed/wounded	2,613 (63.51%)	7,801 (55.43%)	<0.0001
Depleted uranium	61 (1.48%)	132 (0.94%)	0.0027
Destroyed military vehicles	186 (4.52%)	446 (3.17%)	<0.0001
Discharged a weapon	40 (0.97%)	61 (0.43%)	<0.0001
Excessive vibration	802 (19.49%)	2,019 (14.35%)	<0.0001
Fog oils (smoke screen)	146 (3.55%)	311 (2.21%)	<0.0001
Great danger of being killed	993 (24.14%)	2,437 (17.32%)	<0.0001
Industrial pollution	1,012 (24.60%)	2,630 (18.69%)	<0.0001
Ionizing radiation	403 (9.80%)	1039 (7.38%)	<0.0001
JP8 or other fuels	799 (19.42%)	2,131 (15.14%)	<0.0001
Lasers	129 (3.14%)	297 (2.11%)	0.0001
Loud noises	2,176 (52.89%)	5,957 (42.33%)	<0.0001
Paints	532 (12.93%)	1,163 (8.26%)	<0.0001
Pesticides (environmental)	563 (13.68%)	1,250 (8.88%)	<0.0001
Radar/microwaves	492 (11.96%)	1,098 (7.80%)	<0.0001
Sand/dust	2,802 (68.11%)	7,897 (56.11%)	<0.0001
Smoke from burning trash or feces	2,115 (51.41%)	5,899 (41.92%)	<0.0001
Smoke from oil fire	598 (14.54%)	1,402 (9.96%)	<0.0001
Smoke from tent heater	261 (6.34%)	575 (4.09%)	<0.0001
Solvents	407 (9.89%)	864 (6.14%)	<0.0001
Vehicle or truck exhaust fumes	1,812 (44.04%)	4,811 (34.19%)	<0.0001
Other exposure to toxic chemicals	422 (10.26%)	1,109 (7.88%)	<0.0001
2003 and 2008 Questionnaires (*N*)[b]	4,058 (23.62%)	13,121 (76.38%)	
DEET insect repellent	1,801 (44.38%)	4,918 (37.48%)	<0.0001
Gas mask	53 (1.31%)	175 (1.33%)	0.8929
MOPP overgarments	30 (0.74%)	82 (0.62%)	0.4290
Pesticide-treated uniforms	2,316 (57.07%)	6,840 (52.13%)	<0.0001
2008 and 2012 Questionnaires (*N*)[b]	2,078 (17.89%)	9,538 (82.11%)	
Blast or explosion	186 (8.95%)	628 (6.58%)	0.0001
Fall/other event	328 (15.78%)	1,211 (12.70%)	0.0002
Fragment/bullet wound above shoulders	4 (0.19%)	5 (0.05%)	0.0376
Vehicle accident/crash	43 (2.07%)	106 (1.11%)	0.0004

[a]Pearson χ^2.
[b]Number of subjects who completed the survey.

had a *p*-value less than 0.0001 and the AUROC curve was 0.668. As the final model had over a dozen variables, collinearity was investigated. The associations between variables were found to be extremely low. Effect sizes of the exposure variables were modest (OR ranging from 1.22 to 1.38) and lower than those of some of the demographic characteristics. Demographic characteristics with the largest effect sizes included Air Force Guard and Reserve service components, officer rank, and surgeon career field (OR ranging from 0.32 to 0.50). Holding other variables in the model constant, these characteristics were protective with an OR of less than or equal to 0.5; the nurse career field was the risk factor with the strongest positive association (OR: 1.51). Notably, deployment location was not associated with an increased risk of having a PDMH condition.

DISCUSSION

This study was the first analysis of deployment-related occupational/environmental exposures and the risk for incident PDMH conditions in the overall population of USAF health care personnel (i.e., $N \approx$ all). In contrast to other studies of military health care personnel, this study used actual diagnoses as derived from EHR systems to determine the outcome and archived survey data from the post-deployment medical surveillance system to ascertain exposures. Similarly, this study was unique in not utilizing a cross-sectional design (i.e., exposure and outcome were not simultaneously ascertained) with a population of health care personnel, thus the temporal relationship between exposure and outcome could be established.

Multivariable logistic regression analysis revealed that reported occupational/environmental exposures were not strongly associated with incident PDMH conditions. The strongest exposure variable was sand/dust (OR: 1.38, 95% CI: 1.26, 1.52). Prabhakaran and Gunasekar provided a potential biological explanation for this association between sand/dust and mental health conditions based on their work evaluating the effects of Afghanistan sand on rat dopaminergic neuronal

TABLE IV. Logistic Regression Model of Risk Factors for Incident PDMH Conditions.

Variable	Regression Coefficient	Standard Error	OR	95% CI for OR		*p*-Value
				Lower	Upper	
Exposures						
Dead bodies or people killed/ wounded	0.201	0.0423	1.223	1.126	1.329	<0.0001
Great danger of being killed	0.218	0.0466	1.244	1.135	1.362	<0.0001
Loud noises	0.225	0.0472	1.252	1.142	1.373	<0.0001
Pesticide (environmental)	0.279	0.0589	1.322	1.177	1.483	<0.0001
Sand/dust	0.322	0.0482	1.380	1.256	1.517	<0.0001
Demographic characteristics						
Career field:						
Enlisted group 1[a]	−0.521	0.0761	0.594	0.511	0.689	<0.0001
Enlisted group 2[b]	−0.330	0.0563	0.719	0.643	0.802	<0.0001
Nurse	0.411	0.0749	1.509	1.303	1.749	<0.0001
Non-surgical physician	−0.464	0.0949	0.628	0.521	0.756	<0.0001
Surgeon	−1.128	0.1651	0.324	0.231	0.443	<0.0001
Deployments: 2 or more	−0.436	0.0392	0.646	0.599	0.698	<0.0001
Female and either in enlisted group 1[a] or 2[b]	0.309	0.0676	1.362	1.193	1.555	<0.0001
Marital status: single	−0.252	0.0402	0.777	0.718	0.841	<0.0001
Rank: officer	−0.693	0.0662	0.500	0.439	0.569	<0.0001
Service component:						
Air National Guard	−0.791	0.0693	0.453	0.395	0.518	<0.0001
Air Force Reserve	−1.090	0.0824	0.336	0.285	0.394	<0.0001
Unmarried with dependents	0.340	0.0720	1.405	1.219	1.616	<0.0001

[a]Enlisted group 1: aerospace and operational physiology, bioenvironmental engineering, dental assistant, and diagnostic imaging.
[b]Enlisted group 2: cardiopulmonary laboratory, diet therapy, health services management, medical laboratory, ophthalmic, physical medicine, and public health.

cells.[10] They determined that the soluble components of this sand could be toxic to neuronal cells by enhancing reactive oxygen species and impairing mitochondrial function. Gunasekar, quoted in the popular press,[11] asserted that dust in sandstorms contains manganese and other metals with known associations with neurotoxicity, and service members may potentially inhale "toxic particles" that can then be carried to the brain. This exposure might explain post-deployment complaints about respiratory problems and cognitive function, the latter including problems with attention and short-term memory – symptoms that overlap with depression and PTSD. The only other study addressing sand/dust and mental health was by Meo et al, who conducted a cross-sectional survey of 517 healthy volunteers who were exposed to a sandstorm in Riyadh, Saudi Arabia.[12] They observed that 37.5% of the volunteers reported psychological disturbances among other issues such as respiratory problems and sleep disturbances.

With regard to the other statistically significant occupational/environmental exposures, there were few comparative published studies involving military health care personnel. Kolkow et al conducted a cross-sectional survey of 102 medical staff at a single U.S. Navy hospital to identify exposure risk factors for PTSD, depression, and mental health care utilization among medical personnel who had deployed to a combat zone.[7] In their small sample, reported direct and perceived threats of personal harm were associated with an increased risk of PTSD, whereas reported frequent exposure to dead or wounded service members and civilians was not associated with either PTSD or depression. Similarly, Dickstein et al reported that exposure to combat-related stress (such as being in danger of being killed) was associated with increased severity of PTSD.[13] Jones et al conducted a cross-sectional analysis of survey data available on 479 medical personnel and 5,345 non-medical personnel in the United Kingdom Armed Forces who deployed to Iraq.[6] They observed that combat-related traumatic experiences did not explain psychological ill health in medics; however, medical traumatic experiences, such as seeing personnel wounded or killed, giving aid to the wounded, and handling bodies, did explain the psychological ill health in medics.

In this study, accounting for occupational/environmental exposures in the regression analysis did not significantly modify the impact of demographic risk factors as described by the authors in the original cohort study. Protective factors included being single; an officer; a surgeon; a non-surgical physician; in the enlisted career fields of aerospace and operational physiology, bioenvironmental engineering, dental assistant, or diagnostic imaging; in the enlisted career fields of cardiopulmonary laboratory, diet therapy, health services management, medical laboratory, ophthalmic, physical medicine, or public health; a member of the Guard or Reserve component; and having multiple deployments. Risk factors included being a nurse, female and in one of the enlisted groups mentioned in the previous sentence, and unmarried with dependents. Holding the other variables in the model constant, factors with the largest effect sizes included being a surgeon (OR: 0.32) or nurse (OR: 1.51), officer rank (OR: 0.50), and service component (Guard: OR: 0.45; Reserve: OR: 0.34). A review of the relevant literature on

these factors was provided by the authors in their discussion of the results of the original cohort study. Notably, the observation that nurses were at higher risk was consistent with the literature.[8,14] Also, the findings that the Guard and Reserve components showed protective effects were contrary to the published literature.[6] This may be due to the likelihood that these service members receive medical care outside the MHS and thus represents a misclassification or detection bias.

This nested case–control study identified one novel demographic risk factor that was not identified in the original cohort study: an interaction between female gender and the enlisted career fields listed in the previous paragraph. The interaction effect of female gender and enlisted career field was consistent with the findings of Gibbons et al, who conducted a secondary analysis of data from the 2005 Department of Defense Survey of Health-Related Behaviors Among Active Duty Military Personnel to explore the impact of operational stress on active duty health care providers who served at least one tour of duty in the armed conflicts in Iraq or Afghanistan.[4] They compared male versus female and officer versus enlisted health care personnel in terms of measures of self-reported psychological distress and social relations problems. They observed that female enlisted health care personnel reported significantly more psychological distress than their male colleagues.

Study Limitations

One weakness of this study was the ascertainment of the outcome event using diagnosis data extracted from EHRs. It is well known that validated diagnoses represent only visible cases – that is, the iceberg phenomenon, where the number of people with diagnosed disease is a smaller subset of the total number of people with the disease.[15,16] In addition, stigma related to mental health conditions and the impact of the diagnosis on career advancement within military populations would also contribute to underreporting of cases. Finally, Guard and Reserve members do not typically receive all of their medical care from the MHS, thus outcome data would be underreported for this reason as well. Considering these drawbacks to using EHR data, the primary risk to this study was misclassification of cases as controls, which would lead to an underestimation of the strength of association between exposures and incident PDMH conditions.

Another weakness of the study was the limited ability of the fitted model to discriminate between cases and controls given the available demographic and exposure data. The accuracy of a binary model can be assessed based on the AUROC; an area of 1.0 represents perfect discrimination and an area of 0.5 represents model performance no better than chance. Based on the calculated AUROC of 0.668, this study's final statistical model had only marginal performance in correctly identifying most cases and controls. These results were not surprising given the observation by Sareen et al that most mental health conditions are likely attributable to a wide range of putative risk factors such as genetics, childhood adversity, stressful life events, social supports, and personality.[17]

The *a priori* presumption that there were potential etiological associations between exposures and outcomes was another weakness of the study. For example, the limited literature on sand exposure and psychological effects presumes a toxic-mediated mechanism of action. However, it is just as plausible that sand exposure was confounded with situational factors such as living in a perceived foreign environment or being deployed to an austere location. Unfortunately, it is impossible to explore such potential confounders with the existing archived data. The missing contextual data would only be attainable through interviews, which introduce the associated threat of recall bias. Finally, missing data for exposures were set to no response before the investigators received the data. Thus, data that were truly missing were not able to be investigated, which may have resulted in misclassification of exposures. This misclassification could have been differential, resulting in either an overestimate or underestimate of the true association.

Study Strengths

The ascertainment of the outcome from EHRs, using diagnosis codes, was also a strength of the study. The data in the EHRs yielded validated mental health diagnoses that were not constrained to the diagnoses for which ready survey instruments exist. Additionally, EHR data provided the opportunity to detect cases outside the standard post-deployment medical surveillance period. An additional strength of the study was the ascertainment of exposures from archived post-deployment health assessment survey data, thereby minimizing the risk for recall bias.

Suggestions for Future Research

Future studies should more directly determine the nature of wartime exposures for medical personnel to assess the relative contribution of different exposures to the development of PDMH conditions. Although the study did investigate the number of deployments, it did not investigate the number of exposures. This cumulative effect or effect of repeated exposures could be investigated in a future study. Additionally, future research should examine the characteristics (i.e., sensitivity, specificity, positive predictive value, and negative predictive value) of the DD 2976 questionnaire as a screening instrument for mental health conditions in a population of military health care personnel.

Summary

This nested case–control study evaluated deployment-related occupational/environmental exposures and the likelihood for incident PDMH conditions in the population of USAF health care personnel. Occupational/environmental exposures generally had a weak association with incident PDMH conditions. Demographic characteristics were more strongly associated

with incident PDMH conditions; relevant characteristics included being a surgeon or nurse, officer rank, and Guard or Reserve service component. However, this study's final statistical model suggested that the occurrence of incident PDMH conditions was likely attributable to a wider range of risk factors than just the demographic and exposure factors considered.

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