



NOVEMBER 2019

Volume 26
Number 11

MISMR

MEDICAL SURVEILLANCE MONTHLY REPORT



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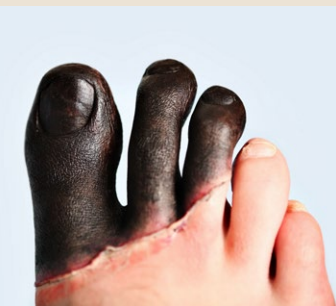
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Mitigating the Risk of Disease From Tick-borne Encephalitis in U.S. Military Populations

Tonya S. Rans, MD (Col, MC, USAF)

Tick-borne encephalitis (TBE) has been a recognized threat to public health and force health protection (FHP) among U.S. military service members and other beneficiaries since at least the 1970s. TBE is caused by TBE virus, which is transmitted to humans within minutes of attachment by infected *Ixodes ricinus* ticks.¹ Chiefly endemic in wooded areas in central and eastern Europe and the Baltic and Nordic countries, transmission occurs mainly in the spring through early autumn.² There is no treatment beyond supportive care, and the vast majority of those infected fully recover. However, despite intensive care intervention, the case fatality rate ranges from 0.5 to 20% depending on the subtype of TBE virus.³⁻⁵ In addition, incomplete recovery with long-term neurologic sequelae can occur in 26–46% of those symptomatic cases in Europe.⁴ Primary prevention for tick bites includes the use of protective clothing, such as long pants/sleeves, and the use of insect repellent,⁶ such as DEET (chemical name: N,N-diethyl-meta-toluamide; 20 to 50% concentration) and picaridin (at least 20% concentration), on the skin. Added protection is provided by treating clothing, tents, and other gear (but not skin) with the repellent permethrin. Several TBE vaccines are available for use in Europe but have not been widely used by U.S. military personnel residing in or deployed to endemic areas because of lack of licensure by the U.S. Food and Drug Administration (FDA).

The U.S. military has been involved in studying the impact of TBE among service members since the 1980s.^{7,8} In 1983, Immuno AG submitted an investigational new drug (IND) application to the FDA for the TBE vaccine FSME-Immun Inject[®] following 25 years of use in Europe.^{9,10} In February 1996, TBE guidance for the U.S. Commander in Chief, Europe, regarding

personnel supporting Operation Joint Endeavor stressed adherence to personal protective measures and, if at high risk, consideration for voluntary receipt of an accelerated, 3-dose TBE vaccine series under an IND protocol.¹¹ Findings from that protocol revealed a 20%, 60%, and 80% seroconversion in the 954 individuals who had received 1, 2, or 3 doses of TBE vaccine, respectively.¹² Of the 959 unvaccinated individuals, 4 (0.42%) demonstrated seroconversion and all were asymptomatic.

In subsequent years, additional publications from Europe demonstrated the scope of TBE and the efficacy of TBE vaccine.¹³⁻¹⁷ In 2011, the World Health Organization published its first position paper on TBE vaccines, and in 2012, TBE became a reportable disease entity among countries in the European Union.^{13,18,19} Collectively, these reports, along with a few recent high-profile cases among U.S. military service members and beneficiaries stationed in Europe, piqued Department of Defense (DoD) interest for an updated review of both the magnitude of TBE disease and an approach toward management within the U.S. military population. However, it was quickly recognized that there are challenges in assessing TBE epidemiology in U.S. military populations, including lack of recognition of the disease among U.S. and host nation providers, incomplete reporting of recognized disease, and misclassification of vaccine administration as true disease in administrative medical records (Armed Forces Health Surveillance Branch, email communications, 23–24 September 2019). These issues resulted in a large amount of concern and uncertainty regarding the threat of TBE to U.S. personnel among not only medical and public health assets within the U.S. European Command (USEUCOM) but also among the supported operational forces.

The 2 articles on TBE in this issue of the *MSMR* constitute an effort to provide a more accurate and precise risk assessment for U.S. military personnel stationed or deployed in USEUCOM through high-quality data that are actionable and inform FHP posture. The first article presents surveillance data including trends in TBE disease from 2006 to 2018 in U.S. military populations in Europe and reports on the efforts to identify and validate cases through multiple data sources and records review. The second article describes an in-depth review of a series of TBE cases that occurred in 2017 and 2018 in the area supported by the U.S. Army Medical Department Activity-Bavaria. These articles highlight the value and power of the centralized Defense Medical Surveillance System (DMSS) in combination with in-depth review of medical records by medical and public health personnel. Together, the 2 articles provide objective evidence that the risk to U.S. service members and beneficiaries of contracting TBE disease in Europe is small but non-zero as well as some limited evidence of increasing risk in recent years.

The risk assessment presented in the first article is relevant to discussions of pursuing additional vaccine options to enhance FHP posture against TBE. DoD Instruction 6205.02²⁰ establishes policy, assigns responsibilities, and provides procedures to establish a uniform DoD immunization program in accordance with the authority in DoD Directive 6200.04²¹ and DoD Instruction 1010.10.²² For infectious diseases identified within the U.S. or in areas with frequent U.S. travelers, the military (similar to the civilian population) relies on primary prevention tools, including FDA-approved immunizations, which are administered in accordance with recommendations from the Centers for Disease Control and Prevention (CDC) and

its Advisory Committee on Immunization Practices (ACIP). However, given the worldwide assignments of DoD beneficiaries, there may be diseases, such as TBE, for which a host nation approved medical product may exist but for which the manufacturer has not submitted an application for U.S. FDA approval.

When there is no available FDA-approved medical product, under DoD Instruction 6200.02,²³ a DoD component may request that the Assistant Secretary of Defense for Health Affairs (ASD-HA) authorize the voluntary use of an investigational medical product for FHP use. Such requests, approval, and implementation must comply with applicable laws and FDA regulations and would involve the provision of the non-FDA approved vaccine for FHP purposes on a voluntary basis under an Emergency Use Authorization or IND protocol. TBE vaccine is currently not an FHP requirement, but the host nation approved product is authorized for voluntary receipt through TRICARE for at-risk DoD beneficiaries in endemic areas of Europe and Asia when vaccine is received from TRICARE authorized providers.²⁴

Both USEUCOM and the Defense Health Agency, through the Immunization Healthcare Branch, the Office of the ASD-HA, and other key DoD stakeholders, are working together to reduce the barriers to vaccination and increase the availability of vaccines to U.S. military beneficiaries stationed in Europe. The challenges surrounding pursuing additional vaccination options and the considerations regarding associated resources to invest will continue to be guided by accurate, precise estimates of the disease burden like the ones provided in this issue of the *MSMR*. Additional seroepidemiologic studies are needed in areas where DoD beneficiaries reside to better define the distribution of TBE and

to guide future TBE vaccination policies in areas with high TBE incidence.²⁵ Furthermore, it cannot be overstated that protective measures against tick-borne diseases, such as TBE, remain grounded in primary prevention.

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Tick-borne Encephalitis Surveillance in U.S. Military Service Members and Beneficiaries, 2006–2018

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The risk of tick-borne encephalitis (TBE) among U.S. military service members and beneficiaries residing in or traveling to Europe has not been assessed since the 1990s. The primary objective of this study was to assess the current risk of TBE in this population. Records of reportable medical events, inpatient and outpatient care, and laboratory test results were searched for TBE cases between 2006 and 2018. There were 8 individuals who met the case definition for TBE over the 13-year interval; 7 cases occurred during 2017 or 2018. Outpatient records did not identify any additional verified cases of TBE but revealed a large number of misclassified diagnoses. The risk of TBE among U.S. military service members and beneficiaries is low but may have increased in recent years. Military members and their dependents residing in Europe or Asia generally have a risk for TBE similar to that of other residents of the host nation. Additionally, there may be locations or activities that place certain individuals or units at increased risk for TBE, thus warranting additional control measures such as active surveillance, enhanced personal protective measures, and vaccination.

In 2012, tick-borne encephalitis (TBE) became a notifiable disease for health-care professionals in Europe to report to public health agencies. Since then, the reported incidence of TBE in Europe has increased. The European Centre for Disease Prevention and Control (ECDC) has concluded that this increase is “consistent with a stable long-term trend” in the European Union, possibly related to environmental conditions.¹ However, it is also possible that this increase may be influenced by enhanced surveillance and diagnosis rather than (or in addition to) a true increase in the incidence of disease.

In 2016, there were 2,674 confirmed cases of TBE reported across the European Union and European Economic Area (EU/EEA), for an overall incidence of 0.6 per 100,000 population.¹ In Germany, the European country in which the greatest number of U.S. military service members

and beneficiaries are stationed, surveillance for TBE (also called Frühsommer-Meningoenzephalitis [FSME] in German) by health authorities began much earlier—in 2001. The majority (89.0%) of TBE cases in Germany reported between 2001 and 2018 occurred in the southern states of Baden-Württemberg (BW) and Bavaria,² both of which contain U.S. military installations and personnel. The annual incidence rate of TBE in Germany during that time period ranged from 0.7 to 2.0 cases per 100,000 persons per year, but the average rate in high-risk areas such as BW and Bavaria was 3.7 (range: 0–48) cases per 100,000 persons per year.² While there was no significant change in TBE incidence noted between 2001 and 2016, the years of 2017 and 2018 were marked by an increase in rates compared to the previous years. Countries in the Baltic states had the highest reported rates of disease, although comparisons between

WHAT ARE THE NEW FINDINGS?

The risk of TBE among U.S. military service members and beneficiaries is low but not negligible. There were 8 cases of TBE among U.S. military service members and beneficiaries between 2006 and 2018, 7 of which occurred in 2017 or 2018. Case finding using outpatient data did not identify additional cases and revealed a large number of misclassified diagnoses.

WHAT IS THE IMPACT ON READINESS AND FORCE HEALTH PROTECTION?

Although the risk of TBE among U.S. military personnel and their dependents is similar to residents of the host nation, there may be locations and activities that place individuals and military units at increased risk. U.S. military public health activities in Europe should ensure the implementation of TBE control measures, including accurate and timely surveillance, proper personal protective and tick avoidance measures, and risk-based vaccination.

countries are difficult because of differences in case definitions, laboratory diagnosis, and other surveillance capabilities.³

U.S. military personnel may engage in activities or behaviors that place them at risk for increased contact with the primary tick vector responsible for TBE transmission, *Ixodes ricinus*. These activities include hiking and camping and outdoor work activities such as forest work or military field exercises.^{4,5} In the 1980s and 1990s, serological studies of U.S. military service members in areas felt to have high risk for TBE found a relatively low seroprevalence (7.2%) among soldiers stationed in Bavaria and Rheinland-Pfalz, Germany,⁶ and low rates of infection (0.9 and 0.7 seroconversions per 1,000 person-months) in Germany and Bosnia, respectively.^{7,8} Only 1 reported case of symptomatic but unconfirmed TBE disease was found in a review

of all inpatient medical records from facilities in central Europe from 1970 to 1983.⁷ Nevertheless, these historical data are not adequate to estimate the current risk to U.S. service members and their dependents, and no assessment of TBE incidence in U.S. military service members or beneficiaries has been published since the 1990s. Furthermore, most prior studies only assessed the risk of TBE in small, focally defined areas, and the risk to U.S. military personnel in the countries of eastern Europe and Asia is unknown.

The primary objective of this study was to determine the number of TBE cases among all U.S. military service members and other beneficiaries worldwide between 2006 and 2018, with a special focus on the risk of TBE in Europe, in order to inform current public health risk assessment and force health protection posture. Although TBE is reportable for all Department of Defense (DoD) beneficiaries in the military's reportable medical events (RMEs) system under the category "arboviral disease,"⁹ some cases might not be reported since TBE is not a reportable disease in the U.S. civilian public health system¹⁰ and because healthcare providers may not be aware of U.S. military and German reporting requirements. The secondary objectives of this study were to examine the completeness and accuracy of various data sources, evaluate existing case-finding algorithms, and determine a valid TBE surveillance case definition for future use.

METHODS

This investigation was reviewed and approved by the Defense Health Agency's Human Research Protections Office as a public health surveillance activity. The population at risk was all U.S. military service members and beneficiaries between 1 January 2006 and 31 December 2018. For the primary analysis, possible TBE cases were identified by examination of all outpatient and inpatient encounters and all RMEs in the Defense Medical Surveillance System (DMSS)¹¹ with a diagnosis of TBE (parent International Classification of Diseases, 9th [ICD-9] and 10th [ICD-10] Revision codes

of 063 or A84, respectively). The TBE case definitions established by the ECDC were used to classify the cases.¹² The clinical criteria included any person with symptoms of inflammation of the central nervous system. To be a confirmed case, the patient had to meet the clinical criteria and have at least 1 of the following 5 laboratory findings: 1) TBE-specific immunoglobulin M (IgM) and immunoglobulin G (IgG) antibodies in blood, 2) TBE-specific IgM antibodies in the cerebrospinal fluid, 3) seroconversion or 4-fold increase of TBE-specific antibodies in paired serum samples, 4) detection of TBE viral nucleic acid in a clinical specimen, or 5) isolation of TBE virus from a clinical specimen. A probable case was defined as any person who met the clinical criteria and had either 1) an epidemiological link or 2) detection of TBE-specific IgM antibodies in a unique serum sample. Only confirmed or probable cases were included in the analysis.

The data repository of the military's electronic medical record (EMR), the Armed Forces Health Longitudinal Technology Application (AHLTA), was reviewed to determine whether the subset of individuals with a record of a TBE diagnosis identified in DMSS records between 2016 and 2018 met the case definition. The review of AHLTA records included examination of all outpatient, inpatient, vaccine, and laboratory records from military treatment facilities (MTFs) in the EMR. Of note, the EMR also included scanned records of inpatient and outpatient encounters that occurred at non-MTFs. Information from hospitalizations at host nation medical facilities was obtained through English translations of the discharge summaries that had also been scanned and uploaded into the EMR. When records were not sufficiently complete to determine whether the patient had been a true TBE case, the patient was contacted via phone (if contact information was available) to obtain additional information.

To evaluate the completeness and accuracy of various alternative data sources and determine a surveillance case definition for future use, additional record reviews were performed. Laboratory records were available from 2006 through 2018 and included all TBE positive lab results from the

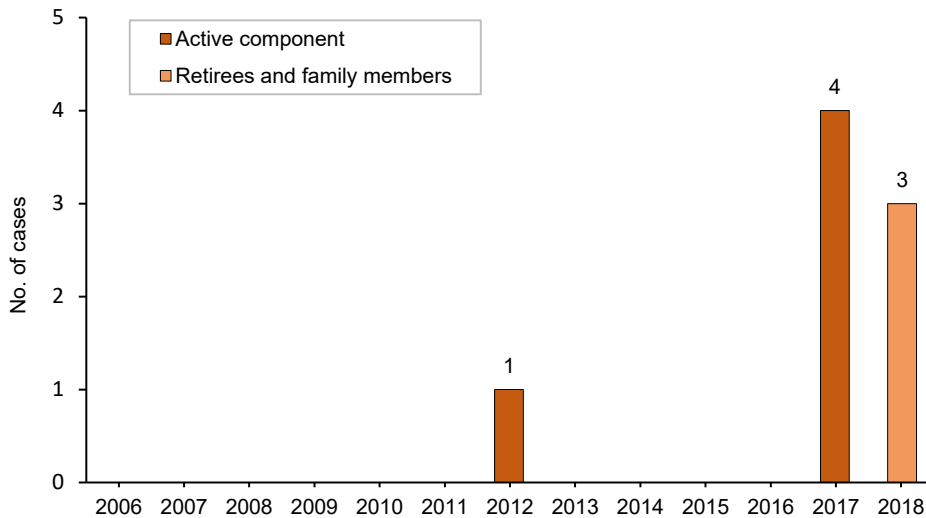
EpiData Center (EDC) at the U.S. Navy and Marine Corps Public Health Center.^{13,14} Of note, these laboratory data included only tests that were performed or reported by an MTF. Findings were also compared with those obtained from direct and purchased care data from TRICARE Europe found in the Military Health System Data Repository (MDR), again using inpatient and outpatient TBE diagnoses that occurred in Europe between 2016 and 2018. The sensitivity and positive predictive value (PPV) of these alternate data sources were estimated in accordance with U.S. Centers for Disease Control and Prevention (U.S. CDC) guidelines for the evaluation of surveillance systems.¹⁵ Because of the small number of cases and lack of appropriate denominators, rates were not calculated.

RESULTS

During 2006–2018, a total of 8 individuals met the TBE case definition (4 confirmed and 4 probable) (**Figure 1**). **Table 1** shows a list of the cases and their characteristics. Laboratory results and disease sequelae were inconsistently documented in the EMR. All cases had reported fever; other symptoms were variable. Five of the cases were service members and 3 were dependent children. Although the numbers are small, the number of cases in 2017–2018 (n=7) greatly exceeded the number from the previous 11 years (n=1), suggesting an increased TBE risk in recent years. The cases all occurred during the expected months of April through November. Of note, no cases were travelers to or residents of any location other than in Europe or in any German states other than BW and Bavaria. None of the cases had a prior history of TBE vaccine.

In order to assess the validity of the TBE definition, the medical records were reviewed for the 166 unique individuals with diagnoses of TBE identified from RMEs and outpatient and inpatient records in the DMSS between 2016 and 2018. Of these unique individuals, 157 had outpatient TBE diagnoses, 15 had inpatient diagnoses, and 5 had RMEs. Of the 166 individuals, 7 (4.2%) were determined to

FIGURE 1. Confirmed or probable TBE cases among U.S. military service members and other beneficiaries, 2006–2018



TBE, tick-borne encephalitis; No., number.

meet the case definition for confirmed (4) or probable (3) TBE. There was 1 additional record of TBE from Navy and Marine Corps Public Health Center laboratory data in an individual who had no TBE records in the DMSS, for a total of 167 individuals with a TBE record. The overlap of records among these different data sources is shown in **Figure 2**. The PPV and sensitivity of the types of records and diagnoses are listed in **Table 2**. All of the 7 cases were found to have either an inpatient (6) or an RME (5) diagnosis of TBE, and 4 had both. All 5 individuals with an RME were hospitalized, although 1 had an inpatient ICD-10 diagnosis code of A86 (viral encephalitis, unspecified). Of the 17 individuals who had either an RME, hospitalization, or lab

TABLE 1. Line listing of confirmed or probable TBE cases among U.S. military service members and beneficiaries, 2006–2018

Case	Category	Month/year	Age (years)	Sex	Patient category	Occupation	Symptoms ^a	Assignment location of SM	Hospital	Exposures noted	TBE lab results	Residual effects
1	Probable	9/2012	33	M	SM	Communications	NR	Vaihingen	Boeblingen	NR	NR	None noted
2	Probable	6/2017	47	M	SM	Other	F, W, MSC	Grafenwoehr	Landstuhl Regional Medical Center	Tick bite 2 weeks prior	Serum: IgM+/IgG- CSF: PCR-	Decreased sensation in fingers, decline in memory, difficulty concentrating > 1 year
3	Probable	7/2017	30	M	SM	Infantry	F, N, HA, MSC	Hohenfels	Regensburg	"no exposure to animals or waters"	"antibody index was highly positive in the serology and CSF"	None noted
4	Confirmed	7/2017	33	M	SM	Explosive ordnance disposal	F, HA, V, D	Grafenwoehr	Kemnath; transferred to Klinikum Weiden	NR	Serum: IgG+/IgM+ CSF: NR	Fatigue, headache, visual disturbances x 1 month
5	Confirmed	11/2017	35	M	SM	Infantry	F, MSC	Hohenfels	Clinic St. Marien Amberg	NR	Serum: IgG+/IgM+ CSF: IgG+/IgM+	Reduced psychomotor function and headache x 10 days
6	Probable	4/2018	2	M	Non-SM	Student	F, NS	Boeblingen	Boeblingen	NR	Serum: IgG-/IgM+ CSF: NR	None noted (failure to thrive noted > 1 year before TBE diagnosis)
7	Confirmed	6/2018	17	M	Non-SM	Student	F, HA, NS, V, W	Stuttgart	Stuttgart	NR	Serum: IgG+/IgM+ CSF: IgG-/IgM-	None noted
8	Confirmed	9/2018	7	F	Non-SM	Student	F, V, W	Boeblingen	Boeblingen	NR	Serum: IgG+/IgM+ CSF: NR	Fatigue, attention/concentration issues x 5 months

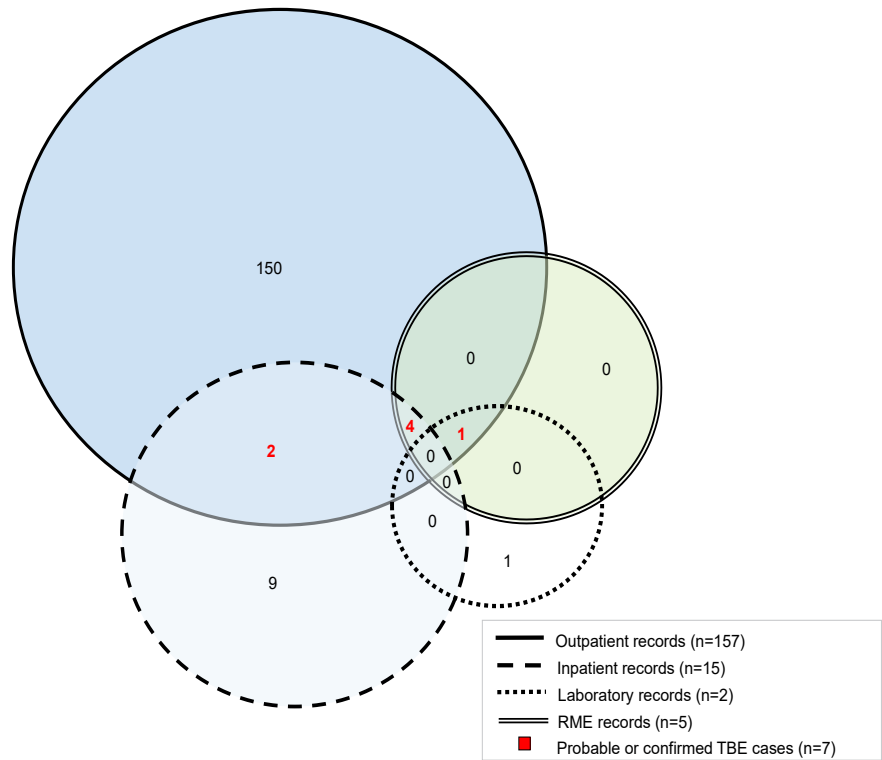
^aSymptoms: NR, not reported; F, fever; W, weakness; MSC, mental status changes; N, nausea; HA, headache; V, vomiting; D, diarrhea; NS, neck stiffness.

TBE, tick-borne encephalitis; M, male; F, female; SM, service member; Non-SM, non-service member; NR, not reported; IgM, immunoglobulin M; IgG, immunoglobulin G; CSF, cerebrospinal fluid; PCR, polymerase chain reaction.

record of TBE, 8 (47.1%) had no evidence of residence or medical care in Europe. Of the 9 hospitalized cases with a misclassified TBE diagnosis, 4 had a diagnosis of another tick-borne disease such as suspected Lyme disease, history of prior Lyme disease, or Rocky Mountain spotted fever. Of the remaining 5 individuals, 1 had long-standing headache symptoms and tested negative for TBE; the others had little or no documentation in their available health records to substantiate a diagnosis of TBE. Of the 157 outpatient diagnoses in the DMSS, 57 were diagnosed in Europe and 100 were either diagnosed outside of Europe or the place of care could not be determined. Of the 50 outpatient diagnoses from Europe that did not meet the case definition, 47 (94.0%) had an encounter for TBE vaccination on the date of TBE diagnosis, 1 (2.0%) had headache or other suggestive symptoms but did not meet the clinical case definition, and 2 (4.0%) had no visits in the EMR on or around the diagnosis date. Of the 100 outpatient cases diagnosed outside of Europe, none met the case definition. Most of these diagnoses occurred in the U.S. among retirees who had no record of care at an MTF. The few who did receive care at an MTF were seen for a tick or other insect bite.

For the period from 2006 through 2015, medical records were reviewed only for those 22 individuals who had an inpatient or RME diagnosis of TBE; only 1 of these individuals met the case definition. All 22 had an inpatient diagnosis of TBE

FIGURE 2. Overlap between record type and TBE diagnosis



Note: The data source for all record types was the DMSS with the exception of laboratory data, which were from NMCPHC. TBE, tick-borne encephalitis; RME, reportable medical event; DMSS, Defense Medical Surveillance System; NMCPHC, Navy and Marine Corps Public Health Center.

and none had an RME.

Finally, the alternative data sources, including EDC laboratory and TRICARE Europe inpatient and outpatient data (from the MDR) were examined to identify additional cases of TBE. There were 2 individuals with a positive laboratory test for TBE

between 2006 and 2018. One individual had already been identified as an RME, and the other did not meet the case definition (sensitivity=14.2%; PPV=50%). TRICARE Europe data from inpatient and outpatient care in Europe revealed 104 individuals with a TBE diagnosis between 2016 and

TABLE 2. Validation of potential TBE case records using record review, by record type, 2016–2018

Record type	No.	No. of confirmed or probable TBE cases	PPV of record	Sensitivity of record to identify confirmed or probable cases of TBE (n=7)
Outpatient	157	7	4%	100%
Inpatient	15	6	40%	86%
RME	5	5	100%	71%
Laboratory positive specimen	2	1	50%	14%
Inpatient or RME or TBE-positive laboratory result	17	7	41%	100%
Inpatient or RME or TBE-positive laboratory result; restricted to records with residence or medical care in Europe	9	7	78%	100%

Note: The data source for all record types was the DMSS with the exception of laboratory data, which were from NMCPHC.

TBE, tick-borne encephalitis; No., number; PPV, positive predictive value; RME, reportable medical event; DMSS, Defense Medical Surveillance System; NMCPHC, Navy and Marine Corps Public Health Center.

2018, 57 of whom were also ascertained from DMSS data. All 7 of the confirmed or probable TBE cases were included in this group (sensitivity=100%; PPV=6.7%). Of the additional 47 individuals identified with a TBE diagnosis who were not ascertained from DMSS data, all had only outpatient TBE diagnoses and none met the case definition for TBE. Thirty-seven (78.7%) of the 47 individuals had a medical encounter for TBE vaccine that was miscoded as TBE disease.

EDITORIAL COMMENT

Of the 8 confirmed or probable cases of TBE among U.S. military service members and beneficiaries during the 13-year surveillance period, 7 occurred in 2017 or 2018. Five of the cases occurred in service members and 3 in children; all cases occurred in Germany in the states of BW or Bavaria. There were no cases of TBE identified among U.S. military service members or beneficiaries traveling to Europe. All but 1 of the cases were hospitalized in a host nation medical facility, and most of the case information was extracted from translations of those hospitalization records. RME surveillance identified 5 of the cases, while laboratory data identified only 1. This is not surprising, as only laboratory tests from MTFs could reliably be obtained and only 1 of the cases was treated in an MTF. Additional case finding using outpatient records revealed large numbers of misclassified cases regardless of data source, largely from medical encounters for TBE vaccine or tick bites that were miscoded as TBE disease. In summary, review of outpatient records identified no additional cases of TBE beyond those already found in RME and inpatient records.

This study provides an update to the current knowledge about the risk of TBE among service members and other beneficiaries. Two previous military studies examined the risk of infection in Germany and Bosnia by assessing seroconversion and found no cases of TBE disease.^{6,8} Another military study reviewed military hospitalization data in Europe and found 1 case of unconfirmed TBE in military

medical records between 1970 and 1983, a time when a much larger number of military personnel were living in Germany.⁷ The incidence rate of TBE in Germany was 2.0 per 100,000 in 2018, with a rate of 3.7 in higher-risk areas such as BW and Bavaria.² Given these rates and based on a population of approximately 50,000 U.S. military service members and beneficiaries dispersed throughout Germany, approximately 1 case per year would be expected. The current study found a very similar overall number of 8 cases over a 13-year period, with all but 1 case identified during the past 2 years. Although small numbers precluded formal statistical testing, the increased number of cases in 2017 and 2018 seen here is similar to the statistically significant increases reported in the German population. Additionally, the experiences in nearby Austria demonstrate the focal nature of TBE and the potential of TBE to emerge in previously unaffected populations despite high vaccination coverage.¹⁶ No cases among military-associated travelers to Europe were seen in the current study, consistent with prior assessments of low risk among most travelers.^{5,17} While only 7 cases of TBE among non-military U.S. travelers were reported between 2000 and 2015, TBE is not a notifiable condition in the U.S., so additional cases may have occurred.⁵

The World Health Organization (WHO) recommends routine TBE vaccination in areas where the disease is highly endemic (defined as a rate of ≥ 5 per 100,000 per year).¹⁸ In regions with lower incidence, WHO recommends targeting only those who are at higher than baseline risk and those that engage in extensive outdoor activities. The U.S. CDC suggests considering vaccination for those “anticipating high-risk exposures” as well as those “living in TBE-endemic countries for an extended period of time” but does not provide specific recommendations related to TBE vaccination.⁵ German policy among the civilian population is to vaccinate beginning at age 1 year if “substantial exposure” is anticipated but otherwise recommends deferring vaccination to age 3 years because of the risk of vaccine-related adverse events in the 1- to 2-year age group.¹⁹ Despite these recommendations, only 27% of the population is estimated to have been vaccinated

against TBE, including only 37–40% in the higher-risk areas of BW and Bavaria.²⁰ German military personnel are all required to receive TBE vaccine in order to be prepared to support national emergency response efforts in endemic areas (K. Erkens, MD, Lt Col, Bundeswehr, email communication, 13 November 2019).

The U.S. military has prior experience with TBE vaccine in Europe. As the vaccine is not licensed by the U.S. Food and Drug Administration (FDA), it must be obtained and administered by host nation providers in Europe outside the U.S. Military Health System. Although many service members and other U.S. military beneficiaries have obtained the vaccine, most of those residing in Germany never receive it. During deployment to Bosnia in the 1990s, the U.S. military’s desire to mitigate TBE risk resulted in TBE vaccine being made available to all DoD personnel at high risk of tick exposure.⁸ Since the vaccine was not licensed by the FDA, it could not be made mandatory for service members, so the vaccine was administered on a voluntary basis under an investigational new drug protocol. After several years, the program was discontinued because of improper documentation and “significant deviation” from the protocol noted by the Government Accounting Office and FDA.²¹ The European Command (EUCOM) and DoD public health leadership are now considering ways to obtain FDA licensure in order to offer TBE vaccine to service members and other beneficiaries living in or traveling to Europe who would be at high risk for TBE exposure. The findings of this study support the current recommendations to vaccinate only those U.S. military service members and beneficiaries at higher risk for TBE acquisition because of residence in an area of high endemicity or participation in extensive outdoor activities.^{5,17,18}

Limitations of this study include a small number of cases and the potential for misclassification of outcome. Patients seeking care at host nation healthcare facilities may be undercounted in this report because these encounters and laboratory results may be insufficiently documented in AHLTA, thus not meeting the case definition applied here. This undercounting is expected to be modest in the

active component because about 82% of these service members' outpatient encounters and 68% of their inpatient encounters occur at MTFs.^{22,23} Although about 90% of non-service member beneficiary encounters occur outside of MTFs,²⁴ potential undercounting is mitigated by the TRI-CARE Overseas Program contract requirement that the contractor translate medical documentation on request (S. Lynch, TRI-CARE Overseas Program Office, email communication, 24 July 2019). Many European MTFs appear to be actively engaged in obtaining/translating purchased care medical documentation and uploading it into the Health Artifact and Image Management Solution (HAIMS), which not only provides documentation for follow-up medical care but also allows for better public health surveillance and response.

Additionally, failure of healthcare providers to recognize TBE and comply with established diagnostic guidelines also may contribute to underestimation of disease.^{19,25} Asymptomatic and subclinical infection and failure of infected individuals to seek care also contribute to the undercounting of cases. The prevalence of subclinical infection would best be assessed by repeating prior studies of seroconversion, which has not been done in Germany since the early 1990s.⁶ On the other hand, recent increases in cases seen in Germany could be attributable to increased surveillance and awareness related to the 2012 ECDC reporting requirement. However, because Germany has required TBE case notification since 2001, this seems less likely. Because many of the hospitalizations attributed to TBE were actually from other tick-borne diseases, further provider education on and awareness of these diseases is indicated, as is ensuring their proper prevention, detection, and response. Updated recommendations on the diagnosis and management of tick-borne diseases in the U.S. are summarized for providers and public health practitioners in a recent U.S. CDC publication.²⁶ Finally, the results from military populations may not be generalizable to U.S. travelers or other populations because of differences in occupational and other outdoor exposures.

Results of this study suggest that the RME case definition performs fairly

well for routine surveillance of TBE. If a more precise estimate is desired, a modest improvement is possible by adding active surveillance of hospitalizations for TBE. However, because of a large proportion of misclassified diagnoses, record reviews are necessary to ascertain whether these additional diagnoses meet the case definition in order to accurately estimate the true TBE burden, assess public health risk, and inform force health protection posture. The ability to perform record review relies on the continuation of the current practice in EUCOM of entering records from care received at host nation medical facilities into the EMR. While the record review conducted in the current study indicated fairly complete documentation in the EMR of care received at host nation medical facilities in Germany, records from hospitalizations in the U.S. were uncommonly found in the EMR. Current surveillance for TBE can be further improved by increased awareness of clinical guidelines for prevention, diagnosis, and treatment in both adults and children.^{17,19,25} Current TBE surveillance can also be improved by increased awareness of and adherence to DoD and host nation reporting requirements so that RMEs can be used to better detect changing trends in TBE incidence. Alternate case finding methods such as laboratory data and outpatient visits are likely to have minimal impact on TBE surveillance because of poor sensitivity and PPV, respectively. Human seroprevalence studies can be a useful complementary surveillance indicator but may be confounded from cross-reactivity to other flaviviruses or viruses of the TBE complex.⁶⁻⁸ Virus prevalence in ticks has been found to be of questionable value in surveillance efforts,²⁷ a finding that is supported by the fact that only 4 of 1,153 ticks (0.3%) tested from passive surveillance at U.S. military installations in Europe from 2012 through 2018 were found to be infected with TBE (A. Cline, MAJ, U.S. Army Public Health Command-Europe, email communication, 20 May 2019).

The number of confirmed or probable TBE cases among U.S. military service members and beneficiaries is low but not negligible and has increased in recent years. Although military members and their

dependents generally have the same risk for TBE as other residents of the host nation and should follow U.S. CDC guidance for travelers to these areas, there may be locations or activities that place these individuals at higher risk for disease. Commanders and U.S. military public health personnel in Europe should be familiar with and anticipate high-risk areas and activities U.S. personnel are likely to encounter. Furthermore, they should ensure that TBE control measures include accurate and timely surveillance, proper personal protective measures (PPMs), tick avoidance, and risk-based vaccination. There are several ways in which individuals and units can reduce their risk of TBE infection. Service members and dependents at risk for TBE should be counseled to avoid consuming unpasteurized dairy products, which can transmit TBE. Service members and dependents should also be counseled to use PPMs, particularly during field exercises and other outdoor activities and when stationed or visiting focal areas of increased TBE risk. PPMs include the DoD repellent system, which consists of maximally covering exposed skin with clothing, applying permethrin to clothing, and applying repellents to remaining exposed skin. Finally, service members and dependents should follow a risk-based strategy for vaccination consistent with national and international recommendations,^{5,17,18,25} and the U.S. military should consider the risks and benefits of compulsory TBE vaccination of service members, similar to German military policy.

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Acknowledgments: The authors would like to acknowledge Mr. Nicholas Seliga, Epi-Data Center, Navy and Marine Corps Public Health Center, for his assistance with the laboratory data; Mr. Shannon Lynch for his assistance obtaining data from the Military Health System Data Repository; Dr. Kay Erkens, Lt Col, Kommando Sanitätsdienst, UAbt VI 2.2, for consultation on German military vaccination policy; LTC Luke Mease for his review of and comments on an earlier version of this manuscript; and MAJ

Amanda Cline, U.S. Army Public Health Command-Europe, for supplying the results from TBE tick surveillance in Europe.

Disclaimer: The views expressed in this article are those of the authors and do not reflect the official policy or position of the Department of Defense or of the U.S. Government.

Sources of support: Support was provided by the Armed Forces Health Surveillance Branch of the Public Health Division at the Defense Health Agency.

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Tick-borne Encephalitis Virus Infection in Beneficiaries of the U.S. Military Healthcare System in Southern Germany

Luke E. Mease, MD (LTC, MC, USA); Scott A. Maddox (MAJ, AN, USA); Matthew R. Noss, DO (MAJ, MC, USA); Sahinaz Whitman

Tick-borne encephalitis (TBE) is caused by a flavivirus usually transmitted to humans via the bite of an infected *Ixodes ricinus* tick. The disease is endemic to central Europe, including Germany where it is a potential threat to U.S. service members and other beneficiaries. This report describes 3 cases of TBE in persons living during 2017 and 2018 in the region of Germany with the highest incidence of TBE: a 36-year-old active duty service member and 2 non-service member beneficiaries aged 17 and 7 years. Each patient presented with debilitating symptoms and, following recovery from their acute illnesses, experienced troubling sequelae for months afterward. The nature of their initial illnesses varied from one another, as did the length and nature of their sequelae. The criteria for diagnosing TBE based upon clinical symptoms and laboratory test results are described. Preventive strategies for protecting residents in Germany from TBE include measures to avoid tick bites. The potential for use of the TBE virus vaccine, not Food and Drug Administration-approved in the U.S. but available in Europe, is discussed.

Tick-borne encephalitis (TBE) is caused by tick-borne encephalitis virus (TBEV), a flavivirus distributed throughout Eurasia. Germany has a relatively high incidence of TBE; in 2016, Germany reported 348 of the 1,534 total cases reported in Europe.¹ There are 3 TBEV subtypes; the subtype most prevalent in Germany is the European subtype, most commonly transmitted by the tick *Ixodes ricinus*. Rarely, TBEV can be transmitted through the ingestion of contaminated dairy products, such as unpasteurized milk.² TBE (known as Früh-sommer-Meningoenzephalitis in German) can cause debilitating meningoencephalitis and long-term sequelae; as such, it poses a health threat to U.S. service members and beneficiaries residing in Germany.³

Typical risk factors for TBE include living in a known risk area and engaging in activities in wooded/forested areas, such as hiking, camping, mushroom gathering, and military field exercises.^{4,5} About half of patients diagnosed with TBE recall a tick bite.⁶ The majority of TBE cases are among males, in both pediatric and adult populations.⁷⁻⁹

TBEV infection can cause a spectrum of illness ranging from subclinical (about one-third of cases) to death (0–1.4%).² Differences in clinical severity are believed to be due to varying virulence of the pathogen and individual factors, most prominently age (older age is associated with increased severity of disease) and comorbidities (especially immunosuppression).¹ Presentation is typically biphasic (72–87% of patients), with a generally subclinical, viremic prodromal phase followed by a more severe second phase. The early phase is characterized by non-specific symptoms such as fever, anorexia, muscle aches, nausea, and vomiting.¹⁰ The most common laboratory findings during the first phase of TBE include leukopenia and thrombocytopenia. It is estimated that 30–50% of symptomatic TBE patients experience only the initial phase of illness, while the remainder experience both phases.¹ Remission between the first and second phases typically lasts about 8 days. The second phase of TBE involves the central nervous system. Patients may have symptoms of meningitis (fever, headache, neck stiffness),

encephalitis (drowsiness, confusion, sensory or motor disturbance), or meningoencephalitis.¹⁰ The most common laboratory findings during the second phase include an elevated white blood cell count, white blood cells in the cerebrospinal fluid (CSF), and increased protein in the CSF. It is common to see an initial predominance of granulocytes in CSF that shifts to a predominance of lymphocytic cells later in the illness. An abnormal electroencephalogram (EEG) is seen in 77% of patients.¹ Sequelae following acute infection are relatively common; 26–46% of patients reported some form of remaining symptoms, such as headache and difficulties with concentration or memory, 6–12 months following acute infection.²

The current report describes 3 cases of TBE that occurred among U.S. Military Health System beneficiaries living in Germany in 2017 and 2018. A large portion of this U.S. population resides in Bavaria and Baden-Württemberg, the German states where 80–90% of German TBE cases occur. There is 1 large U.S. military installation located in a county (“Landkreis” in German) that consistently reports some of the highest incidence rates of TBE in Germany.¹¹ Cases of TBE described here were identified through the U.S. military’s reportable medical event reporting system—the Disease Reporting System internet (DRSi)—and case details were extracted from Armed Forces Health Longitudinal Technology Application (AHLTA) electronic medical records. Case ascertainment also used inpatient documents from German hospitals, translated and scanned into AHLTA. Individuals were included as cases if they met the European Centre for Disease Prevention and Control (ECDC) definition of TBE requiring 1) clinically apparent disease of the central nervous system and 2) valid laboratory documentation of current TBEV infection in the patient. ECDC laboratory criteria for confirmation of current TBEV infection include at least 1 of the following 5: TBE-specific immunoglobulin M and G (IgM and IgG, respectively)

antibodies in blood, TBE-specific IgM antibodies in CSF, seroconversion or 4-fold increase of TBE-specific antibodies in paired serum samples, detection of TBE viral nucleic acid in a clinical specimen, or isolation of TBEV from a clinical specimen.^{3,12} Diagnosis with TBE-specific IgM and IgG antibodies in blood is the most common method of laboratory confirmation in Germany given the clinical course of TBE (IgM and IgG last longer in serum than the virus does) and clinical simplicity (a single serum sample is easier to draw than CSF or multiple sera samples).¹³

Case 1

In November 2017, a 36-year-old male, active duty service member presented to a German hospital with fever and delirium. The patient had no known history of a tick bite and was unimmunized against TBE. The patient lived and worked near Hohenfels, Bavaria, Germany, and was frequently in forested, woody, and grassy areas (always in the local region) as part of his military duties.

A companion reported that the patient had experienced fever for approximately 1 week, altered personality at work (including falling asleep there), and left-sided hemiparesis, which appeared on the day of presentation. This is consistent with the published literature, with focal, unilateral, and upper body areas being the most commonly affected by neurological abnormalities, when present.¹ At the hospital, the patient complained of headaches, retrobulbar pain, and recurring numbness of the left arm and exhibited several episodes of confusion. Rash (not further described in the hospital record) was noted on physical exam.

The patient was too agitated for lumbar puncture (LP) to be performed; accordingly, he was sedated, after which LP was successful. CSF showed moderate pleocytosis consistent with viral meningoencephalitis. An EEG showed a moderately severe, generalized alteration with encephalitic involvement due to known meningitis.

Initially admitted to intensive care, the patient was moved to regular care as he improved. The patient had persistent headaches and what the hospital record described as “general psychomotor slowing and reactions.” Upon admission, the patient was promptly treated with antibacterial and antiviral medications, initially ampicillin, acyclovir, and ceftriaxone. As results of testing

became available, the antimicrobials were stopped in a stepwise manner. The patient was diagnosed with TBE on the basis of the compatible clinical presentation and positive serum TBE IgG and IgM antibodies. The patient gradually improved over 10 days of hospitalization. Upon discharge, 2 weeks of rest at home were recommended.

Following discharge, this soldier reported generalized fatigue, weakness in arms and shoulders, imbalance, headaches, and trouble with memory/focus lasting for several months. Although the fatigue and weakness gradually improved after 4–5 months, headaches persisted for over 6 months. These symptoms mostly resolved; however, he reported intermittent difficulties with memory, focus, and persistent headaches.

Case 2

In June 2018, a 17-year-old male presented to a U.S. military hospital emergency department (ED) with right-sided frontal headache. The patient lived near Stuttgart, Baden-Württemberg, Germany. The patient noted no tick bite, was unimmunized for TBE, and reported no pertinent outdoor activities. He had a multiyear history of recurrent headaches and reported that his current headache was greater in intensity but in the same location as previous headaches. The patient denied nausea, vomiting, sensitivity to light or sounds, numbness, focal weakness, stiff neck, and fever. He was treated with intramuscular ketorolac (an antiinflammatory drug used to treat pain), intravenous fluids (IV), and IV antiemetics. Computed tomography (CT) scan showed no acute abnormalities. The patient improved significantly with treatment and was diagnosed with tension headache, prescribed butalbital/acetaminophen/caffeine, and released from the ED.

The following day, the patient presented to his regular outpatient clinic for a recommended follow-up. Since discharge from the ED, he had developed fever (39.3°C), worsened headache, neck stiffness, vomiting, photophobia, muscle aches, and dizziness. He reported having a cold recently, but symptoms of his cold had reportedly resolved before the onset of the headache and were mild enough that he did not seek care for them. These symptoms could be consistent with biphasic presentation, reported in about 80% of cases in Germany.¹

The patient was referred to a local German hospital and admitted for possible meningitis. Upon presentation, he was still febrile (39.7°C), with meningismus and mild throat inflammation. Blood tests showed leukocytosis, elevated C-reactive protein, and low overall IgG. CSF showed leukocytosis, pleocytosis, and increased protein. Magnetic resonance imaging (MRI) showed no evidence of meningitis or encephalitis. Chest x-ray findings were consistent with bronchopneumonia with left basal consolidation. Urinalysis was positive for protein, ketones, bilirubin, and urobilinubin. An EEG was normal.

On the third day of hospitalization, the patient had low oxygen saturation values (down to 84%) and was transferred to intensive care. The following day, the patient's oxygen saturation improved and he was transferred back to regular care.

Upon admission, the patient was promptly treated with antibacterial and antiviral medications (initially ampicillin, acyclovir, ceftriaxone) and analgesia (ibuprofen, paracetamol, metamizole, and tramadol). On the same day as his intensive care unit transfer, the patient received a one-time, high dose of systemic corticosteroids. He was diagnosed with TBE based on his clinical presentation and positive serum TBE IgG and IgM antibodies. Of note, there was no evidence of TBE IgG or IgM in the CSF.

Following 9 days of hospitalization with gradual improvement, the patient was discharged from the hospital in stable condition. After discharge, the patient experienced fatigue that was disruptive to his work and led to medical follow-up. The fatigue persisted for approximately 3 months before complete resolution.

Case 3

In September 2018, a 7-year-old female developed worsening headache, photophobia, fever (reported 40°C), nausea, vomiting, and diarrhea over 2 days. She lived near Stuttgart, Baden-Württemberg, Germany, and was unimmunized against TBE. Her family reported hiking in Germany twice (in May and September of 2018), with no known tick bite or other pertinent travel. Outpatient evaluation yielded a diagnosis of unspecified viral illness for which she was prescribed oral rehydration therapy and antipyretics. Of note, nausea and vomiting are common presenting symptoms of TBE, especially among pediatric patients.⁹

Upon outpatient follow-up the next day, the patient had experienced no improvement. The patient's parents were instructed to go to a local German hospital, where the patient was admitted with the complaints described above and neck stiffness. On hospital day 1, her condition continued to deteriorate.

LP was performed on hospital day 1. The patient's CSF showed pleocytosis, leukocytosis, and an increased albumin ratio, indicative of a breakdown in the blood-brain barrier consistent with meningitis. The patient's CSF had a positive TBE IgG index. The TBE IgG index is a diagnostic calculation that compares TBE IgG concentrations in the CSF to TBE IgG concentrations in the serum, controlling for total IgG concentrations in both the CSF and serum. A positive TBE IgG index (higher levels of TBE IgG in the CSF than in the serum) demonstrates intrathecal production of TBE antibodies, an indicator of active TBE infection.¹³ Serum was positive for TBE IgG and IgM. Of note, serum was also IgM positive for herpes simplex virus and enterovirus; however, upon expert consultation, no other good evidence for another (non-TBE) etiology was found among the diseases for which the patient was tested, and this case is consistent with a typical TBE infection in childhood (G. Dobler, MD, Lt Col, Bundeswehr, email communication, 09 April 2019).

An EEG (hospital day 3) was abnormal with right temporo-parieto-occipital slowing and a one-time spike-wave complex on the right frontal side. MRI (hospital day 3) showed prominent superficial cranial vessels and sphenoidal and maxillary sinusitis but no evidence of encephalitis. An EEG (hospital day 7) was normal.

Despite aggressive antipyretic treatment, the patient had persistent fevers during the first 4 inpatient days (ranging between 38° and 40°C) before defervescing on hospital day 4. She received IV glucose/electrolyte solutions for 7 days. Upon admission, she was promptly treated with antibacterial and antiviral medications, initially ampicillin, acyclovir, and ceftriaxone. There appears to have been no significant delay in treatment or diagnosis in this case.

Following 8 days of hospitalization, the patient was discharged in stable condition. Following hospital discharge she suffered significant difficulties with focus (in general) and school. Before infection, she

was doing better in school than a twin sister. After infection, her twin was doing better and the patient had significant school difficulties. As of March 2019, the patient continued to have persistent, periodic headaches and to be much less energetic than before the infection. She was reported to be much more socially withdrawn.

The patient was unimmunized against TBE; however, 1 week before the patient first developed symptoms, her family had contacted the military clinic to seek TBE vaccination. The referral process was started; however, given multiple steps in the process, the actual appointment for vaccination with a German clinic was set for 3–4 weeks later. In the interim, the patient developed TBE.

EDITORIAL COMMENT

Although cases of TBE among U.S. travelers to Europe and Asia have been described previously, this is the first report to describe such cases among U.S. service members and beneficiaries living in Europe.¹⁴ The cases illustrate the significant acute debilitation that TBE can cause. For example, case 1, an active duty soldier, experienced dramatically altered mental status, the most common neurological symptom.¹ TBE infection in this patient caused a 10-day hospitalization, 2 weeks of convalescence, and months of headaches, decreased energy, and difficulty with concentration; ultimately, there was a significant negative impact on his readiness and deployability. Moreover, all patients reported some degree of sequelae following resolution of TBEV infection, which is well described in the literature.^{1,8} For example, case 3 (a 7-year-old female) experienced cognitive issues. Pediatric patients often recover physically more quickly from TBE, but cognitive sequelae represent a prominent concern.⁹ This report also documents that those residing in a risk area (e.g., in Bavaria and Baden-Württemberg, Germany) are potentially more likely to contract TBE. Two of 3 cases reported participation in traditionally high-risk outdoor activities; however, none recalled a tick bite.

These cases also highlight the potential for underdiagnosis of TBE in the U.S. population stationed in Germany. Underdiagnosis occurs in the European healthcare

system and is thought to be due to lack of knowledge of the disease and the relative rarity of “classical” clinical presentation of TBE.⁵ If TBE is underdiagnosed by European providers, it is likely also underdiagnosed by U.S. providers in Europe. Lack of education and awareness of this Eurasian zoonosis could preclude its consideration in a differential diagnosis. Furthermore, there are challenges accessing diagnostics in the U.S. healthcare system. Serum testing for TBE IgG and IgM is available; however, it is not included as a standard test and requires direct coordination with the laboratory and a specific request for the test. Failure to appropriately diagnose TBE could lead to unnecessary testing, the lack of a definitive diagnosis, and an unclear prognosis. Such uncertainty might prevent a patient from accessing or utilizing appropriate specialty services during and after the acute phase of the disease. Delays in diagnosis could also contribute to similar problems. Although cases 2 and 3 did have to visit a U.S. provider twice before referral, review of the clinical details (especially the lack of meningeal signs during the first visit for both) suggest there was no delay in appropriate referral to the German system; similarly, there appears to be no delay in appropriate diagnosis once in the German system.

Efforts should be made to prevent TBE in the U.S. military population in Europe. These efforts could mirror the German, Austrian, or World Health Organization (WHO) public health approaches, which include promoting avoidance of ticks/TBE (i.e., through behavior, appropriate clothing, repellants, and early detection of ticks) and vaccination (either targeted or in the general population).⁵ The Austrian national government recommends and financially supports generalized vaccination for all residents.¹⁵ German military personnel are all required to receive TBE vaccine in order to be prepared to support national emergency response efforts in endemic areas (K. Erkens, MD, Lt Col, Bundeswehr, email communication, 13 November 2019). The WHO recommends vaccination of all age groups in areas of high pre-vaccination prevalence (defined as $\geq 5/100,000$ per year).^{16,17} The German government recommends vaccination for all individuals 1 year or older in risk areas defined by the Robert Koch Institute.³ One study showed overall TBE vaccination in

Germany at 27%, with higher rates in the highest-risk areas (i.e., 37–40% in Bavaria and Baden-Württemberg).¹⁸

None of the cases reported here had been immunized against TBEV. Vaccination is safe and effective in preventing TBE. Unfortunately, no TBE vaccines are U.S. Food and Drug Administration (FDA) approved, so purchase or administration by the U.S. government, including U.S. military medical facilities, is legally restricted. Administration of TBE vaccine is, however, now covered by insurance for U.S. military members in Europe. It is administered only at the level of individual patients, not at the level of military units or as a public health effort. Through the efforts of the European Command (EUCOM) and medical providers in Germany, TBE vaccine was approved for all active duty beneficiaries through TRICARE Eurasia in May 2014. Before that (starting in February 2008), it was identified as a TRICARE eligible benefit for dependents and retirees. Currently, obtaining TBE vaccination among the U.S. military population requires a multistep process. The patient must first visit their military provider, who verifies the patient will be in country long enough to complete the series (at least 1 year longer). A referral to a German provider is then made. The patient then makes an appointment and visits the German provider. The patient receives the initial dose then arranges to receive the additional doses 3 and 9 months later. Given the requirement to obtain a special referral and arrange for and make multiple visits to an off-post provider, it is possible this process is sufficiently onerous to deter some from seeking the vaccine. Department of Defense (DoD) civilian employees with private (non-TRICARE) health insurance receive healthcare through the German medical system. Accordingly, for DoD civilians, TBE vaccine has been covered for as long as it has been standard of care in the German healthcare system.

Also, because the vaccine is not offered through the U.S. Military Health System or as part of any force health protection efforts, it is possible that U.S. military personnel may simply not be aware of the vaccine or indications for seeking it. There have been efforts by EUCOM and the Defense Health Agency to obtain FDA approval for TBE vaccine. FDA approval would likely simplify the process of obtaining vaccine and

would allow it to be considered as a force health protection and/or public health measure. For example, the U.S. military could explore mirroring the German military model of requiring TBE vaccination for all military personnel stationed in Bavaria and Baden-Württemberg. Cost-benefit analysis of TBE vaccination of U.S. military personnel would inform this consideration.

This case study has several limitations. Many clinical details were derived from German medical records; all were translated by certified medical translators in an approved but imperfect process. Sequelae and preceding symptoms were ascertained up to a year after TBE infection and were likely subject to recall bias.

U.S. Military Health System beneficiaries living in Germany are at risk of TBE. It is important for providers caring for military service members in Europe to be proficient in the recognition and treatment of TBE. The U.S. military healthcare system in Europe should educate providers and patients regarding TBE risk, prevention, diagnosis, and treatment. The U.S. military healthcare system should also strive to make TBE diagnostics readily available to its providers and beneficiaries either internally or through enhanced cooperation with the German healthcare system.

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Acknowledgments: The authors thank Prof. Dr. Gerhard Dobler (Lt Col, Bundeswehr) for his thoughtful consultation, MAJ Daniel Weinstein for his valuable operational perspective, Mr. Joey Scaletta for his consistent support, and COL James Mancuso for his excellent guidance.

Funding: All work described herein was performed as part of paid regular duties as part of employment by the U.S. Government.

Disclaimer: The views expressed are those of the author(s) and do not reflect the official policy of the Department of the Army, the Department of Defense, or the U.S. Government.

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Update: Cold Weather Injuries, Active and Reserve Components, U.S. Armed Forces, July 2014–June 2019

From July 2018 through June 2019, a total of 513 members of the active (n=446) and reserve (n=67) components had at least 1 medical encounter with a primary diagnosis of cold injury. The crude overall incidence rate of cold injury for all active component service members in 2018–2019 (36.5 per 100,000 person-years [p-yrs]) was slightly higher than the rate for the 2017–2018 cold season (35.8 per 100,000 p-yrs) and was the highest rate during the 5-year surveillance period. In 2018–2019, frostbite was the most common type of cold injury among active component service members in all 4 services. Among active component members during the 2014–2019 cold seasons, overall rates of cold injuries were generally highest among males, non-Hispanic black service members, the youngest (less than 20 years old), and those who were enlisted. As noted in prior *MSMR* updates, the rate of all cold injuries among active component Army members was higher in women than in men because of a much higher rate of frostbite among female soldiers. The number of cold injuries associated with overseas deployments during the 2018–2019 cold season (n=24) was the highest count during the 5-year surveillance period.

Cold weather injuries are of significant military concern because of their adverse impact on operations and the high financial costs of treatment and disability.^{1,2} In response, the U.S. Armed Forces have developed and improved training, doctrine, procedures, and protective equipment and clothing to counter the threat from cold environments.^{3–8} Although these measures are highly effective, cold injuries have continued to affect hundreds of service members each year because of exposure to cold and wet environments.⁹

The term cold weather injuries is used to describe injuries that have a central effect, such as hypothermia, as well as those that primarily affect the peripheries of the body, such as frostbite and immersion injuries. The human physiologic response to cold exposure is to retard heat loss and preserve core body temperature, but this response may not be sufficient to prevent hypothermia if heat loss is prolonged.⁹ Moreover, the response includes constriction of the

peripheral (superficial) vascular system, which may result in non-freezing injuries or hasten the onset of actual freezing of tissues (frostbite).⁹

Hypothermia occurs when the core temperature of the body falls below 95°F.⁷ The most common mechanisms of accidental hypothermia are convective heat loss to cold air and conductive heat loss to water.¹⁰ Freezing temperatures are not required to produce hypothermia.¹⁰ In response to cold stress, peripheral blood vessels constrict and the hypothalamus stimulates heat production through shivering and elevated thyroid, adrenal, and catecholamine activity.¹⁰ The sympathetic nervous system mediates further vasoconstriction to minimize heat loss by reducing blood flow to the extremities, where the most cooling occurs.¹⁰ As the body's basal metabolic rate decreases, core temperature falls, body functions slow down, and muscular and cerebral functions are impaired.¹⁰ Neurologic functioning begins declining even above a core body temperature of 95°F.¹¹ Severe hypothermia

WHAT ARE THE NEW FINDINGS?

For all active component service members, the rate of cold weather injuries in 2018–2019 was the highest of the last 5 seasons. Cold injury rates were much higher among members of the Marine Corps and Army. Cold injuries associated with deployment during 2018–2019 were much more numerous than any of the previous 4 years; frostbite accounted for most such injuries.

WHAT IS THE IMPACT ON READINESS AND FORCE HEALTH PROTECTION?

U.S. military forces will likely be deployed in cold, northern latitudes for peacekeeping and national security operations because of the opening of new shipping lanes in the Arctic Ocean. Such operations will require renewed emphasis on effective cold weather injury prevention strategies and adherence to the policies and procedures in place to protect service members against such injuries.

can lead to pulmonary edema, reduced heart rate, coma, ventricular arrhythmias (including ventricular fibrillation), and asystole.^{10–12}

Cold injuries affecting the body's peripheries can be classified as freezing and non-freezing injuries.¹³ Freezing peripheral injury is defined as the damage sustained by tissues when exposed to temperatures below freezing.¹³ The tissue damage of frostbite is the result of both direct cold-induced cell death and the secondary effects of microvascular thrombosis and subsequent ischemia.¹⁴ Rapid freezing generally results in extra- and intracellular ice crystal formation.¹⁵ These crystals cause direct injury to the cell membrane that results in cellular dehydration, lipid derangement, electrolyte fluxes, membrane lysis, and cell death.^{14–16} An inflammatory process follows, resulting in tissue ischemia and additional cell death.¹⁵ The initial cellular damage and the ensuing inflammatory processes are worsened with thawing of the affected area.^{15,16} With rewarming, edema from melting ice

crystals leads to epidermal blister formation and ischemia-reperfusion injury may be initiated¹⁴⁻¹⁶; vasoconstriction and platelet aggregation caused by inflammatory mediators, prostaglandins, and thromboxanes exacerbate ischemia.¹⁷ The areas of the body most frequently affected by frostbite include the ears, nose, cheeks, chin, fingers, and toes.^{18,19} A substantial proportion of patients with peripheral frostbite experience permanent changes in their microcirculation and disruption of local neurological functions (e.g., reduced sensation in the affected area).¹⁹ Although most frostbite damage is minor, severe injury may lead to impaired functioning and ability to work because of cold hypersensitivity, chronic ulceration, vasospasm, localized osteoarthritis, and/or chronic pain.^{14,19}

Non-freezing peripheral cold injury includes a spectrum of localized injuries to the soft tissues, nerves, and vasculature of distal extremities that result from prolonged exposure (12 to 48 hours) to wet, cold (generally 32 to 59°F) conditions; the injury process generally happens at a slower rate in warmer water.^{13,20} Although non-freezing peripheral cold injuries most often involve feet (immersion foot), any dependent body part can be affected by the condition, including the hands.²¹ Immersion foot generally presents as waterlogging of the feet, with the most marked effect occurring in the soles.^{17,20} The foot becomes hyperemic (increased blood flow), painful, and swollen with continuous exposure; progression to blistering, decreased blood flow, ulceration, and gangrene is gradual.^{17,20} Long-term complications of non-freezing cold injury such as immersion foot are similar to (e.g., hypersensitivity to cold, chronic pain) and as debilitating as (e.g., severe pain provoked by walking) those produced by frostbite.^{14,16,17,20}

Factors that increase the risk of cold weather injuries include outdoor exposure, inadequate and/or wet clothing, cold water submersion, older age, exhaustion, dehydration, inadequate caloric intake, alcohol use, smoking (frostbite), previous cold injury (frostbite or immersion foot), chronic disease (e.g., peripheral vascular disease, diabetes), and medications that impair compensatory responses (e.g., oral antihyperglycemics, beta-blockers, general

anesthetic agents).^{12-14,17-19} Situational factors that increase risk of immersion foot include immobility, wet socks, and constricting boots.^{17,22}

Traditional measures to counter the dangers associated with cold environments include minimizing loss of body heat and protecting superficial tissues through means such as protective clothing, shelter, physical activity, and nutrition. However, military training or mission requirements in cold and wet weather may place service members in situations where they may be unable to be physically active, find warm shelter, or change wet or damp clothing.²⁻⁴

For the military, continuous surveillance of cold weather injuries is essential to inform steps to reduce their impact as well as to remind leaders of this predictable threat. Since 2004, the *MSMR* has published annual updates on the incidence of cold weather injuries that affected U.S. military members during the 5 most recent cold seasons.²³ The content of this 2019 report addresses the occurrence of such injuries during the cold seasons from July 2014 through June 2019. The timing of the annual updates is intended to call attention to the recurring risks of such injuries as winter approaches in the Northern Hemisphere, where most members of the U.S. Armed Forces are assigned.

METHODS

The surveillance period was 1 July 2014 through 30 June 2019. The surveillance population included all individuals who served in the active or reserve component of the U.S. Armed Forces at any time during the surveillance period. For analysis purposes, “cold years” or “cold seasons” were defined as 1 July through 30 June intervals so that complete cold weather seasons could be represented in year-to-year summaries and comparisons.

Because cold weather injuries represent a threat to the health of individual service members and to military training and operations, the U.S. Armed Forces require expeditious reporting of these reportable medical events (RMEs) via one of the service-specific electronic reporting systems;

these reports are routinely incorporated into the Defense Medical Surveillance System (DMSS). For this analysis, the DMSS and the Theater Medical Data Store (which maintains electronic records of medical encounters of deployed service members) were searched for records of RMEs and inpatient and outpatient care for the diagnoses of interest (frostbite, immersion injury, and hypothermia). A case was defined by the presence of an RME or of any qualifying International Classification of Diseases, 9th or 10th Revision (ICD-9 and ICD-10, respectively) code in the first diagnostic position of a record of a healthcare encounter (**Table 1**). The Department of Defense guidelines for RMEs require the reporting of cases of hypothermia, freezing peripheral injuries (i.e., frostbite), and non-freezing peripheral injuries (i.e., immersion injuries, chilblains).²⁴ Cases of chilblains are not included in this report because the condition is common, infrequently diagnosed, usually mild in severity, and thought to have minimal medical, public health, or military impacts. Because of an update to the Disease Reporting System internet (DRSi) medical event reporting system in July 2017, the type of RMEs for cold injury (i.e., frostbite, immersion injury, hypothermia) could not be distinguished using RME records in DMSS data. Instead, information on the type of RME for cold injury between July 2017 and June 2019 were extracted from the DRSi and then combined with DMSS data.

To estimate the number of unique individuals who suffered a cold injury each cold season and to avoid counting follow-up healthcare encounters after single episodes of cold injury, only 1 cold injury per

TABLE 1. ICD-9/ICD-10 diagnostic codes for cold weather injuries

	ICD-9	ICD-10 ^a
Frostbite	991.0, 991.1, 991.2, 991.3	T33.*, T34.*
Immersion hand and foot	991.4	T69.0*
Hypothermia	991.6	T68.*

^aAn asterisk (*) indicates that any subsequent digit/character is included.
ICD, International Classification of Diseases.

individual per cold season was included. A slightly different approach was taken for summaries of the incidence of the different types of cold injury diagnoses. In counting types of diagnoses, 1 of each type of cold injury per individual per cold season was included. For example, if an individual was diagnosed with immersion foot at one point during a cold season and then with frostbite later during the same cold season, each of those different types of injury would be counted in the tally of injuries. If a service member had multiple medical encounters for cold injuries on the same day, only 1 encounter was used for analysis (hospitalizations were prioritized over ambulatory visits, which were prioritized over RMEs).

Annual incidence rates of cold injuries among active component service members were calculated as incident cold injury diagnoses per 100,000 person-years (p-yrs) of service. Annual rates of cold injuries among reservists were calculated as cases per 100,000 persons using the total number of reserve component service members for each year of the surveillance period. Counts of persons were used as the denominator in these calculations because information on

the start and end dates of active duty service periods of reserve component members was not available.

The numbers of cold injuries were summarized by the locations at which service members were treated for these injuries as identified by the Defense Medical Information System Identifier (DMIS ID) recorded in the medical records of the cold injuries. Because such injuries may be sustained during field training exercises, temporary duty, or other instances for which a service member may not be located at his/her usual duty station, DMIS ID was used as a proxy for the location where the cold injury occurred.

The new electronic health record for the Military Health System, MHS GENESIS, was implemented at several military treatment facilities during 2017. Medical data from sites using MHS GENESIS are not available in the DMSS. These sites include Naval Hospital Oak Harbor, Naval Hospital Bremerton, Air Force Medical Services Fairchild, and Madigan Army Medical Center. Therefore, medical encounter and person-time data for individuals seeking care at any of these facilities during 2017–30 June 2019 were not included in this analysis.

2018–2019 cold season

From July 2018 through June 2019, a total of 513 members of the active (n=446) and reserve (n=67) components had at least 1 medical encounter with a primary diagnosis of cold injury (**Table 2**). The Army contributed almost three-fifths (59.6%; n=266) of all cold injury diagnoses in the active component during the 2018–2019 cold season. Across the services during this period, the rate of cold injury diagnoses was highest among active component Marine Corps members (62.2 per 100,000 p-yrs). The 115 members of the Marine Corps diagnosed with a cold injury represented more than one-quarter (25.8%) of all affected active component service members. Navy service members (n=20) had the lowest service-specific rate of cold injuries (7.1 per 100,000 p-yrs) (**Table 2, Figure 1**).

This update for 2018–2019 represents the third time that annual rates of cold injuries for members of the reserve component were estimated. Army personnel (n=46) accounted for more than two-thirds

TABLE 2. Any cold injury (1 per person per year), by service and component, July 2014–June 2019

	Army		Navy		Air Force		Marine Corps		All services	
	No.	Rate ^a	No.	Rate ^a	No.	Rate ^a	No.	Rate ^a	No.	Rate ^a
Active component										
All years (2014–2019)	1,189	51.0	147	9.7	213	13.6	460	49.9	2,009	31.7
Jul 2014–Jun 2015	208	41.9	35	10.9	50	16.1	116	62.4	409	31.1
Jul 2015–Jun 2016	233	48.5	30	9.2	31	10.0	72	39.1	366	28.2
Jul 2016–Jun 2017	202	43.6	35	11.0	42	13.5	71	38.8	350	27.4
Jul 2017–Jun 2018	280	62.4	27	9.8	45	14.3	86	46.8	438	35.8
Jul 2018–Jun 2019	266	60.2	20	7.1	45	14.2	115	62.2	446	36.5
Reserve component										
All years (2014–2019)	216		10		36		59		321	
Jul 2014–Jun 2015	45	20.1	3	4.6	13	16.8	10	21.2	71	17.1
Jul 2015–Jun 2016	33	14.6	2	3.1	4	5.3	7	15.1	46	11.1
Jul 2016–Jun 2017	38	17.0	1	1.5	8	10.5	11	23.8	58	14.1
Jul 2017–Jun 2018	54	25.1	3	4.6	5	6.6	17	36.8	79	19.6
Jul 2018–Jun 2019	46	22.1	1	1.6	6	8.1	14	30.8	67	17.1
Overall, active and reserve components										
All years (2014–2019)	1,405		157		249		519		2,330	
Jul 2014–Jun 2015	253		38		63		126		480	
Jul 2015–Jun 2016	266		32		35		79		412	
Jul 2016–Jun 2017	240		36		50		82		408	
Jul 2017–Jun 2018	334		30		50		103		517	
Jul 2018–Jun 2019	312		21		51		129		513	

^aFor active component, rate is per 100,000 person-years. For reserve component, rate is per 100,000 persons. No., number.

(68.7%) of all reserve component service members (n=67) affected by cold injuries (Table 2). During this period, the rate of cold injury diagnoses was highest among reserve component Marine Corps members (30.8 per 100,000 persons) and lowest among reserve component Navy members (1.6 per 100,000 persons).

The overall rate of cold injuries for the reserve component and the rates for each of the services except the Air Force were lower than in the 2017–2018 season. Among reserve component members, the most pronounced decrease in service-specific rates of cold injuries between the 2017–2018 and 2018–2019 seasons was seen in the Marine Corps.

When all injuries were considered, not just the numbers of individuals affected, frostbite was the most common type of cold injury (n=241; 52.3% of all cold injuries) among active component service members in 2018–2019 (Tables 3a–3d). In the Air Force and Navy, 84.8% and 70.0%, respectively, of all cold injuries were frostbite, whereas the proportions in the Army (48.7%) and Marine Corps (44.8%) were much lower. Among active component Marine Corps members, the number and rate of frostbite injuries were the highest of the past 5 years. For all active component service members, the proportions of total cold weather injuries that were hypothermia and immersion injuries were 17.4% and 30.4%, respectively (data not shown). Among active component Navy members, the number and rate of immersion injuries in 2018–2019 were the lowest of the 5-year surveillance period (Table 3b). The rate of immersion injury cases in the Army was 41.4% higher than the rate for the 2017–2018 cold season (Table 3a).

Five cold seasons: July 2014–June 2019

The crude overall incidence rate of cold injury for all active component service members in 2018–2019 (36.5 per 100,000 p-yrs) was slightly higher than the rate for the 2017–2018 cold season (35.8 per 100,000 p-yrs) and was the highest rate during the 5-year period (Table 2, Figure 1). Throughout the surveillance period, the cold injury rates were consistently higher among active component members of the

FIGURE 1. Annual incidence rates of cold injuries (1 per person per year), by service, active component, U.S. Armed Forces, July 2014–June 2019

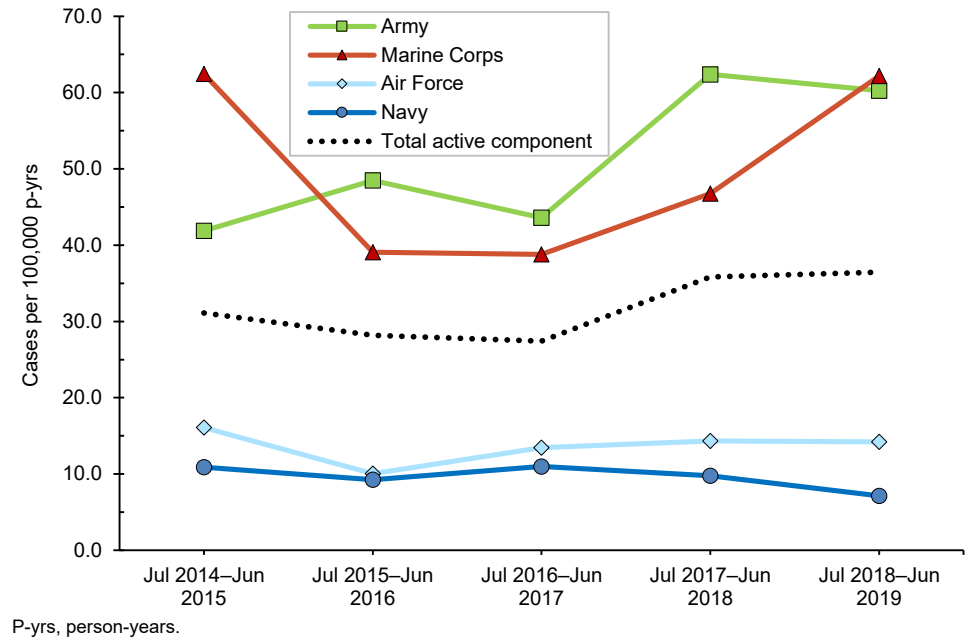
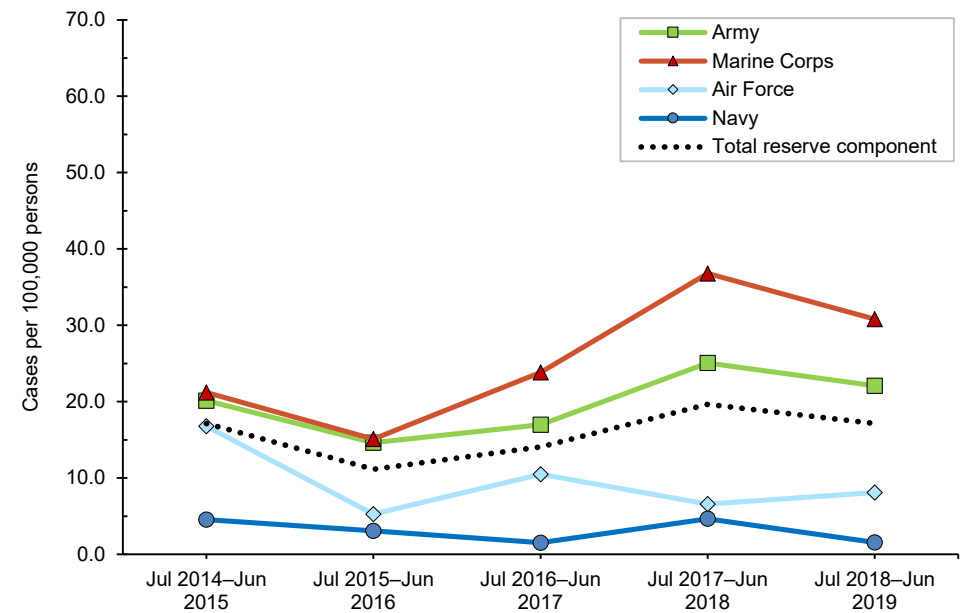


FIGURE 2. Annual incidence rates of cold injuries (1 per person per year), by service, reserve component, U.S. Armed Forces, July 2014–June 2019



Army and the Marine Corps than among those in the Air Force and Navy (Figure 1). In 2018–2019, the service-specific incidence rate for active component Army members (60.2 per 100,000 p-yrs) was slightly lower than the 2017–2018 Army rate (62.4 per 100,000 p-yrs). For the Marine Corps, the active component rate for 2018–2019 was

28.1% higher than the rate for the previous season and 60.6% higher than the rate for the 2015–2016 season. As was true for the active component, service-specific annual rates of cold injuries among reserve component members were consistently higher among those in the Army and Marine Corps than among those in the Air Force

TABLE 3a. Counts and incidence rates of cold injuries (1 per type per person per year), active component, U.S. Army, July 2014–June 2019

	Frostbite		Immersion foot		Hypothermia		All cold injuries	
	No.	Rate ^a	No.	Rate ^a	No.	Rate ^a	No.	Rate ^a
Total	699	30.0	302	13.0	218	9.4	1,219	52.3
Sex								
Male	565	28.4	273	13.7	192	9.6	1,030	51.7
Female	134	39.5	29	8.5	26	7.7	189	55.7
Race/ethnicity								
Non-Hispanic white	246	18.6	124	9.4	122	9.2	492	37.2
Non-Hispanic black	328	66.3	112	22.6	53	10.7	493	99.7
Other/unknown	125	24.3	66	12.8	43	8.3	234	45.4
Age group (years)								
<20	53	31.9	40	24.1	33	19.9	126	75.9
20–24	300	43.2	138	19.9	106	15.2	544	78.3
25–29	149	28.2	72	13.6	53	10.0	274	51.9
30–34	101	26.7	28	7.4	17	4.5	146	38.7
35–39	53	18.9	19	6.8	5	1.8	77	27.5
40–44	22	13.1	3	1.8	3	1.8	28	16.7
45+	21	18.0	2	1.7	1	0.9	24	20.5
Rank								
Enlisted	620	33.1	274	14.6	197	10.5	1,091	58.3
Officer	79	17.2	28	6.1	21	4.6	128	27.9
Military occupation								
Combat-specific ^b	231	39.8	131	22.6	108	18.6	470	80.9
Motor transport	35	48.8	9	12.5	8	11.1	52	72.4
Repair/engineering	114	23.9	51	10.7	27	5.7	192	40.3
Communications/intelligence	180	31.2	63	10.9	50	8.7	293	50.8
Healthcare	37	15.4	13	5.4	7	2.9	57	23.7
Other/unknown	102	26.6	35	9.1	18	4.7	155	40.4
Cold year (July–June)								
2014–2015	136	27.4	19	3.8	55	11.1	210	42.3
2015–2016	126	26.2	73	15.2	42	8.7	241	50.2
2016–2017	133	28.7	33	7.1	37	8.0	203	43.8
2017–2018	168	37.4	74	16.5	44	9.8	286	63.7
2018–2019	136	30.8	103	23.3	40	9.1	279	63.2

^aRate per 100,000 person-years.
^bInfantry/artillery/combat engineering/armor.
 No., number.

or Navy (**Figure 2**). The most pronounced increase (143.8%) in rates was seen among reserve component Marine Corps members between the 2015–2016 and 2017–2018 seasons.

During the 5-year surveillance period, the rates of cold injuries among members of the active components of the Navy, Air Force, and Marine Corps were higher among men than women. Among active component Army members, the overall rate among women (55.7 per 100,000 p-yrs) was 7.7% higher than the rate among men (51.7 per 100,000 p-yrs). In all of the services during 2014–2019, women had lower rates of immersion injury and hypothermia than did males but higher rates of frostbite (except in the Navy and Air Force) (**Tables 3a–3d**). For active component service members in all 4 services combined, the overall rate of cold injury was 31.4% higher among males (33.6 per 100,000 p-yrs) than among females (25.6 per 100,000 p-yrs) (**data not shown**).

In all of the services, overall rates of cold injuries were higher among non-Hispanic black service members than among those of the other race/ethnicity groups. In particular, within the Marine Corps and Army and for all services combined, rates of cold injuries were more than twice as high among non-Hispanic black service members than among either non-Hispanic white service members or those in the “other/unknown” race/ethnicity group (**Tables 3a–3d**). The major underlying factor in these differences is that the rate of frostbite among non-Hispanic black members from all services combined was more than 3 times that of the other race/ethnicity groups, with the biggest differences apparent in the Marine Corps (more than 5 times) and the Army (more than 2 times) (**data not shown**). Additionally, across the active components of all services during 2014–2019, non-Hispanic black service members had incidence rates of cold injuries greater than the rates of other race/ethnicity groups in nearly every military occupational category (**data not shown**).

Across the services, rates of cold injuries were generally highest among the youngest service members (less than 20 years old) and tended to decrease with increasing age (**Tables 3a–3d**). Enlisted

TABLE 3b. Counts and incidence rates of cold injuries (1 per type per person per year), active component, U.S. Navy, July 2014–June 2019

	Frostbite		Immersion foot		Hypothermia		All cold injuries	
	No.	Rate ^a	No.	Rate ^a	No.	Rate ^a	No.	Rate ^a
Total	60	3.9	48	3.2	39	2.6	147	9.7
Sex								
Male	51	4.1	44	3.6	35	2.8	130	10.5
Female	9	3.1	4	1.4	4	1.4	17	5.9
Race/ethnicity								
Non-Hispanic white	25	3.2	20	2.6	22	2.8	67	8.6
Non-Hispanic black	13	5.6	8	3.4	9	3.9	30	12.9
Other/unknown	22	4.3	20	3.9	8	1.6	50	9.8
Age group (years)								
<20	8	9.2	6	6.9	6	6.9	20	23.0
20–24	10	2.2	21	4.6	13	2.8	44	9.6
25–29	25	6.5	12	3.1	15	3.9	52	13.5
30–34	7	2.7	5	2.0	2	0.8	14	5.5
35–39	7	3.9	3	1.7	3	1.7	13	7.3
40–44	1	1.0	1	1.0	0	0.0	2	2.1
45+	2	3.2	0	0.0	0	0.0	2	3.2
Rank								
Enlisted	52	4.1	46	3.7	38	3.0	136	10.8
Officer	8	3.1	2	0.8	1	0.4	11	4.2
Military occupation								
Combat-specific ^b	10	10.5	0	0.0	3	3.2	13	13.7
Motor transport	5	8.3	5	8.3	10	16.6	20	33.1
Repair/engineering	17	2.6	23	3.5	8	1.2	48	7.3
Communications/intelligence	6	2.5	4	1.7	4	1.7	14	5.8
Healthcare	10	5.6	4	2.2	5	2.8	19	10.7
Other/unknown	12	4.1	12	4.1	9	3.1	33	11.4
Cold year (July–June)								
2014–2015	16	5.0	13	4.0	7	2.2	36	11.2
2015–2016	8	2.5	11	3.4	10	3.1	29	8.9
2016–2017	7	2.2	15	4.7	13	4.1	35	11.0
2017–2018	15	5.4	8	2.9	4	1.4	27	9.8
2018–2019	14	5.0	1	0.4	5	1.8	20	7.1

^aRate per 100,000 person-years.
^bInfantry/artillery/combat engineering/armor.
 No., number.

members of all 4 services had higher rates than officers. In the Army, Navy, and Air Force, rates of all cold injuries combined were highest among service members in combat-specific (infantry/artillery/combat engineering/armor) and motor transport occupations (Tables 3a–3c).

During the 5-year surveillance period, the 2,330 service members who were affected by any cold injury included 2,009 (86.2%) from the active component and 321 (13.8%) from the reserve component. Of all affected reserve component members, 67.3% (n=216) were members of the Army (Table 2). Overall, soldiers accounted for slightly more than three-fifths (60.3%) of all cold injuries affecting active and reserve component service members (Table 2, Figure 3).

Of all active component service members who were diagnosed with a cold injury (n=2,009), 190 (9.5% of the total) were affected during basic training. The Army (n=72) and Marine Corps (n=109) accounted for 95.3% of all basic trainees affected by cold injuries (data not shown). Additionally, during the surveillance period, 71 service members who were diagnosed with cold injuries (3.5% of the total) were hospitalized, and the vast majority (90.1%) of the hospitalized cases were members of either the Army (n=41) or Marine Corps (n=23) (data not shown).

Cold injuries during deployments

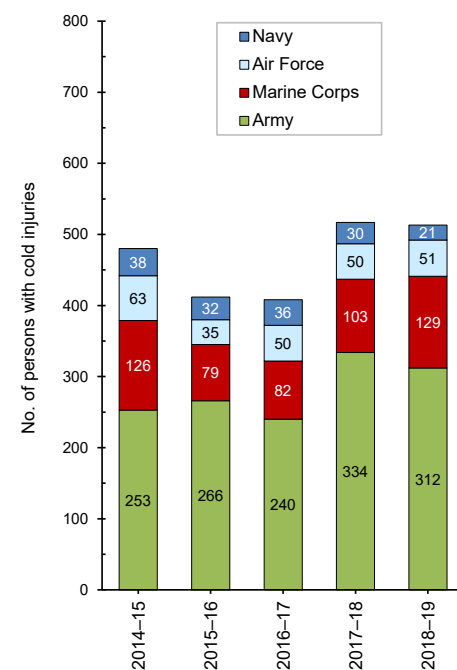
During the 5-year surveillance period, a total of 76 cold injuries were diagnosed and treated in service members deployed outside of the U.S. (data not shown). Of these, 32 (42.1%) were frostbite, 35 (46.1%) were immersion injuries, and 9 (11.8%) were hypothermia. Of these 76 cold injuries, slightly less than one-third (31.6%) occurred in the most recent cold season. There were 24 cold injuries during the 2018–2019 cold season but only 13 during 2014–2015, 11 each during 2015–2016 and 2016–2017, and 17 during 2017–2018 (data not shown). Frostbite accounted for more than half (n=13; 54.2%) of the cold weather injuries diagnosed and treated in service members deployed outside of the U.S. during the 2018–2019 cold season. The vast majority of these frostbite cases were male (84.6%) and almost half (47.2%)

TABLE 3c. Counts and incidence rates of cold injuries (1 per type per person per year), active component, U.S. Air Force, July 2014–June 2019

	Frostbite		Immersion foot		Hypothermia		All cold injuries	
	No.	Rate ^a	No.	Rate ^a	No.	Rate ^a	No.	Rate ^a
Total	170	10.9	18	1.2	28	1.8	216	13.8
Sex								
Male	144	11.5	16	1.3	24	1.9	184	14.7
Female	26	8.5	2	0.7	4	1.3	32	10.4
Race/ethnicity								
Non-Hispanic white	96	9.8	12	1.2	18	1.8	126	12.9
Non-Hispanic black	35	16.7	3	1.4	6	2.9	44	21.0
Other/unknown	39	10.4	3	0.8	4	1.1	46	12.3
Age group (years)								
<20	12	15.7	3	3.9	5	6.5	20	26.1
20–24	77	17.9	5	1.2	8	1.9	90	20.9
25–29	40	10.0	5	1.2	6	1.5	51	12.7
30–34	21	7.1	4	1.4	1	0.3	26	8.8
35–39	11	5.3	1	0.5	5	2.4	17	8.2
40–44	5	4.9	0	0.0	1	1.0	6	5.9
45+	4	8.1	0	0.0	2	4.0	6	12.1
Rank								
Enlisted	151	12.0	17	1.4	24	1.9	192	15.3
Officer	19	6.2	1	0.3	4	1.3	24	7.9
Military occupation								
Combat-specific ^b	5	46.1	0	0.0	0	0.0	5	46.1
Motor transport	3	27.5	0	0.0	0	0.0	3	27.5
Repair/engineering	64	13.0	6	1.2	4	0.8	74	15.1
Communications/intelligence	31	8.9	1	0.3	5	1.4	37	10.6
Healthcare	12	8.0	1	0.7	1	0.7	14	9.4
Other/unknown	55	10.0	10	1.8	18	3.3	83	15.1
Cold year (July–June)								
2014–2015	42	13.5	4	1.3	4	1.3	50	16.1
2015–2016	19	6.2	4	1.3	8	2.6	31	10.0
2016–2017	32	10.3	6	1.9	6	1.9	44	14.1
2017–2018	38	12.1	2	0.6	5	1.6	45	14.3
2018–2019	39	12.3	2	0.6	5	1.6	46	14.5

^aRate per 100,000 person-years.
^bInfantry/artillery/combat engineering/armor.
 No., number.

FIGURE 3. Numbers of service members who had a cold injury (1 per person per year), by service and cold season, active and reserve components, U.S. Armed Forces, July 2014–June 2019



No., number.

were 24 years old or younger (**data not shown**). Army members accounted for more than two-fifths (46.2%) of the frostbite cases diagnosed among service members deployed outside of the U.S. Afghanistan was recorded as the location of diagnosis for 4 of these frostbite cases; information on the locations where the diagnoses were made was unavailable for 7 of these 13 frostbite cases (**data not shown**).

Cold injuries by location

During the 5-year surveillance period, 21 military locations had at least 25 incident cold injuries among active and reserve component service members (**Figure 4**). Among these locations, those with the highest 5-year counts of incident injuries were Fort Wainwright, AK (n=152); Army Health Clinic Vilseck, Germany (n=141); Marine Corps Recruit Depot Parris Island/Beaufort, SC (n=97); Naval Medical Center San Diego, CA (n=75); Fort Drum, NY (n=74); and Fort Campbell, KY (n=73) (**data not shown**). During the 2018–2019

TABLE 3d. Counts and incidence rates of cold injuries (1 per type per person per year), active component, U.S. Marine Corps, July 2014–June 2019

	Frostbite		Immersion foot		Hypothermia		All cold injuries	
	No.	Rate ^a	No.	Rate ^a	No.	Rate ^a	No.	Rate ^a
Total	158	17.1	185	20.1	124	13.4	467	50.7
Sex								
Male	145	17.1	183	21.6	119	14.1	447	52.8
Female	13	17.3	2	2.7	5	6.7	20	26.6
Race/ethnicity								
Non-Hispanic white	61	10.8	134	23.8	60	10.7	255	45.3
Non-Hispanic black	64	69.1	14	15.1	27	29.2	105	113.4
Other/unknown	33	12.4	37	13.9	37	13.9	107	40.1
Age group (years)								
<20	23	18.1	101	79.4	42	33.0	166	130.5
20–24	90	20.6	69	15.8	61	13.9	220	50.2
25–29	24	14.9	11	6.8	17	10.6	52	32.3
30–34	11	12.1	2	2.2	2	2.2	15	16.5
35–39	8	13.4	2	3.4	2	3.4	12	20.1
40–44	1	3.3	0	0.0	0	0.0	1	3.3
45+	1	6.6	0	0.0	0	0.0	1	6.6
Rank								
Enlisted	130	15.9	178	21.8	118	14.4	426	52.2
Officer	28	26.6	7	6.6	6	5.7	41	38.9
Military occupation								
Combat-specific ^b	69	34.7	16	8.0	45	22.6	130	65.4
Motor transport	3	7.6	4	10.2	5	12.7	12	30.5
Repair/engineering	11	4.8	13	5.7	7	3.0	31	13.5
Communications/intelligence	32	15.5	6	2.9	10	4.9	48	23.3
Healthcare	0	0.0	0	0.0	0	0.0	0	0.0
Other/unknown	43	17.3	146	58.8	57	23.0	246	99.1
Cold year (July–June)								
2014–2015	18	9.7	76	40.9	23	12.4	117	63.0
2015–2016	22	11.9	20	10.8	30	16.3	72	39.1
2016–2017	32	17.5	23	12.6	17	9.3	72	39.3
2017–2018	34	18.5	32	17.4	24	13.1	90	49.0
2018–2019	52	28.1	34	18.4	30	16.2	116	62.7

^aRate per 100,000 person-years.
^bInfantry/artillery/combat engineering/armor.
 No., number.

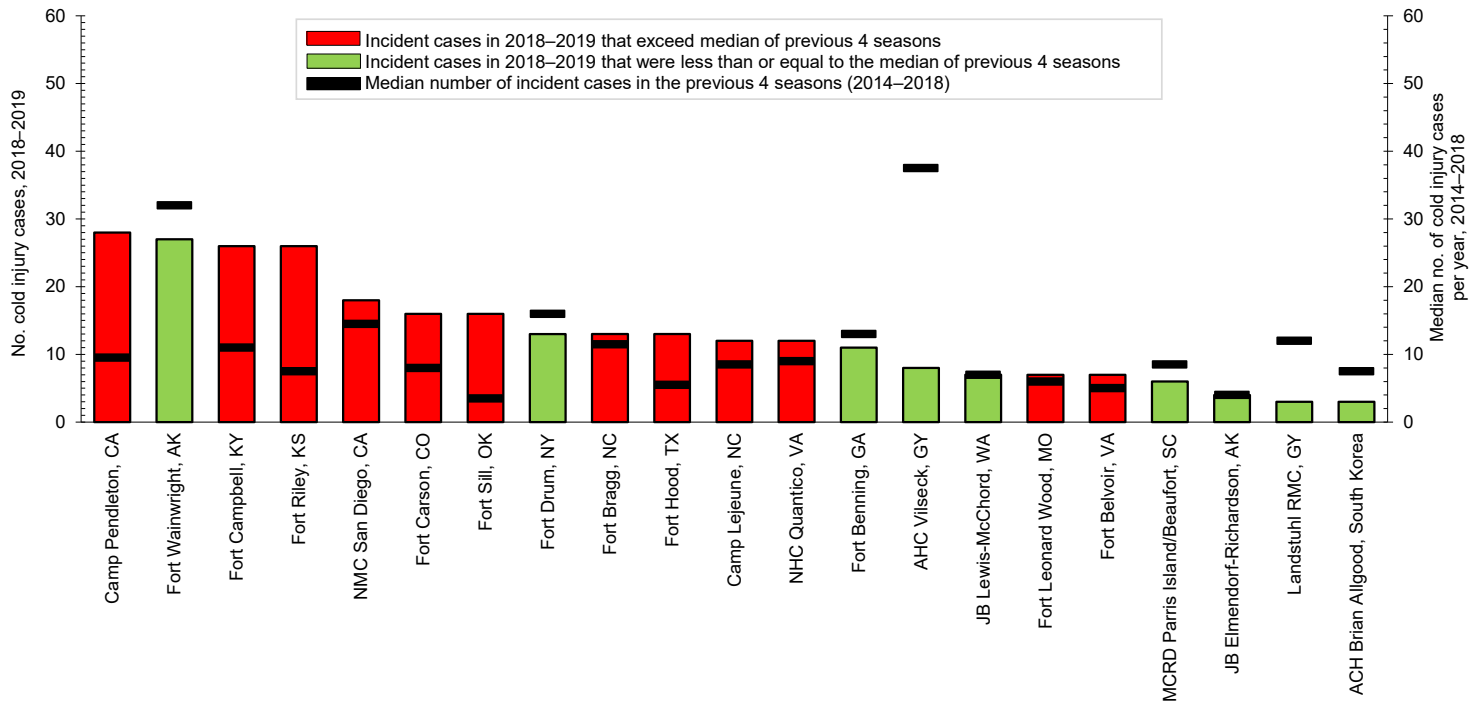
cold season, the numbers of incident cases of cold injuries were higher than the counts for the previous 2017–2018 cold season at 10 of the 21 locations (**data not shown**). The most noteworthy increases were observed at the Marine Corps' Camp Pendleton and the Army's Fort Riley and Fort Sill, where there were 28, 26, and 16 total cases diagnosed at each location in 2018–2019, respectively, compared to just 13, 11, and 5, respectively, the year before (**data not shown**). **Figure 4** shows the numbers of cold injuries during 2018–2019 and the median numbers of cases for the previous 4 years for those locations that had at least 25 cases during the surveillance period. For 9 of the 21 installations, the numbers of cases in 2018–2019 were equal to or less than the median counts for the previous 4 years.

EDITORIAL COMMENT

Between the 2017–2018 and 2018–2019 cold seasons, there was a slight increase in the crude overall incidence rate of cold injuries among U.S. active component service members; the overall rate among reserve component members decreased slightly during this period. For active component service members in the Marine Corps, the rate of all cold injuries in 2018–2019 was the highest since the 2014–2015 season.

In 2018–2019, frostbite was the most common type of cold injury among active component service members. Factors associated with increased risk of cold injury in previous years were again noted during the most recent cold season. Compared to their respective counterparts, males, non-Hispanic black service members, the youngest (less than 20 years old), and those who were enlisted had higher overall rates of cold injuries. Increased rates of cold injuries affected nearly all enlisted and officer occupations among non-Hispanic black service members. Of note, rates of frostbite were markedly higher among non-Hispanic blacks compared to non-Hispanic whites and those in the other/unknown race/ethnicity group. These differences have been noted in prior *MSMR* updates, and the results of several studies suggest that other factors (e.g., physiologic

FIGURE 4. Annual numbers of cold injuries (cold season 2018–2019) and median numbers of cold injuries (cold seasons 2014–2018) at locations with at least 25 cold injuries during the surveillance period, active component, U.S. Armed Forces, July 2014–June 2019



No., number; NMC, Naval Medical Center; NHC, Naval Health Clinic; AHC, Army Health Clinic; GY, Germany; JB, Joint Base; MCRD, Marine Corps Recruit Depot; RMC, Regional Medical Center; ACH, Army Community Hospital.

differences and/or previous cold weather experience) are possible explanations for increased susceptibility.^{9,14,25–27} The number of cold injuries associated with deployment during 2018–2019 was more than the number in any other year during the surveillance period; frostbite accounted for the majority of the cold weather injuries in service members deployed outside of the U.S. during the 2018–2019 cold season.

The opening of sea lanes in the Arctic Ocean increases the likelihood that U.S. military forces will be deployed in the cold, northern latitudes for peacekeeping and national security operations.^{28–31} This shift will require renewed emphasis on effective cold weather injury prevention strategies and increased focus on adherence to the policies and procedures in place to protect service members against such injuries. It should be noted that this analysis of cold injuries was unable to distinguish between injuries sustained during official military duties (training or operations) and injuries associated with personal activities not related to official duties. RMEs for non-freezing peripheral injuries were excluded if “chilblains”

was listed in the case comments; however, there may have been some RMEs for chilblains that were misclassified as immersion injury if chilblains was not listed in the case comments. To provide for all circumstances that pose the threat of cold weather injury, service members should know well the signs of cold injury and how to protect themselves against such injuries whether they are training, operating, fighting, or recreating under wet and freezing conditions.

The most current cold injury prevention materials are available at <https://phc.amedd.army.mil/topics/discond/cip/Pages/Cold-Weather-Casualties-and-Injuries.aspx>.

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Cold-Weather Casualties

In cold weather you need to make an extra effort to stay healthy.
Go the extra mile to avoid serious illness.

Clothing

- Remember the acronym C-O-L-D when wearing clothing in cold weather (C: Keep it Clean; O: avoid Overheating; L: wear clothing Loose and in Layers; D: keep clothing Dry).
- Change into dry clothing each day and whenever clothing becomes wet.
- Wash and dry feet and put on dry socks at least twice daily.

Eyes

- Use sunglasses with side protection in snow-covered areas.

Skin

- Keep your skin clean, covered and dry.
- Use gloves to handle all equipment and fuel products.
- Avoid cotton clothing - it holds moisture.
- No skin camouflage below 32 °F - it obscures detection of cold injuries.

Carbon Monoxide

- Use only Army-approved heaters in sleeping areas.
- Never sleep in idling vehicles.
- Post a fire guard when using a heater in sleeping areas.

Look after your battle buddy!

Tell your instructor if you notice any of these problems:

- Skin that is swollen, red, darkened, painful, tender.
- Body parts that are numb, tingling, bleeding, blistered, swollen, tender, waxy looking.
- Uncontrollable shivering, drowsiness, mental slowness, lack of coordination.
- Dizziness, weakness, fatigue, blurred vision.
- Eyes that are painful, red, watery, or gritty feeling.
- Headache, confusion, dizziness, excessive yawning, cherry red lips and mouth.



For additional information refer to U.S. Army TB MED 508.
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Medical Surveillance Monthly Report (MSMR)

Armed Forces Health Surveillance Branch
11800 Tech Road, Suite 220
Silver Spring, MD 20904

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ISSN 2158-0111 (print)

ISSN 2152-8217 (online)

