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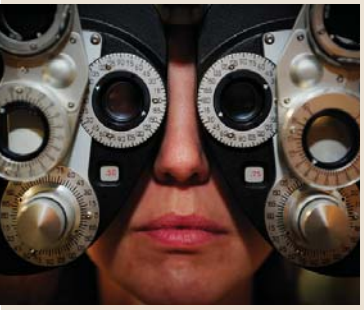

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Characterizing the Relationship Between Tick Bites and Lyme Disease in Active Component U.S. Armed Forces in the Eastern United States

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Lyme disease (LD) is the most commonly diagnosed vector-borne illness in the U.S. Analysis of ticks that are removed from patients (rather than collected from the environment) may inform LD surveillance. In this ecological study, LD rates among active component U.S. Armed Forces in the eastern U.S. were compared with tick data from the U.S. Army Public Health Command Human Tick Test Kit Program (HTTKP) covering the same geographic region. In the population of service members in the study sample, mean annual LD incidence was 52.2 per 100,000 person-years (95% CI ± 7.6 per 100,000) between 1 January 2006 and 31 December 2012. A 10% increase in the rate of ticks submitted to the HTTKP corresponded to an increase in LD incidence of 5.7% ($p<0.01$). Where *Borrelia burgdorferi* infection of *Ixodes scapularis* ticks was high (20% or greater tick infection prevalence), tick removal rates explained 53.7% of the annual variation in LD incidence ($p=0.01$). These data support using location-specific rates of ticks removed while feeding on active component service members to complement LD surveillance.

Lyme disease (LD) is the most commonly diagnosed vector-borne illness both in the U.S. military and in the general U.S. population.[1,2] For an infection to occur, the causative spirochete, *Borrelia burgdorferi,* must be transmitted in the saliva of a vector tick during feeding.[3] In the U.S., *Ixodes scapularis* (eastern U.S.) and *Ixodes pacificus* (Pacific Coast) are the vectors of LD. Although the mechanics of infection are straightforward, the surveillance of human disease remains challenging. In areas where LD is endemic, for example, high rates of infection are often accompanied by decreased case reporting (underreporting bias).[4] Syndromic surveillance efforts are, in turn, complicated by the wide range of clinical pathology that is attributable to *B. burgdorferi* infection **(Table 1)**. Finally, serologic surveillance is limited by the fact that tests are not universally ordered, are not required for diagnosis, exhibit a time lag to positivity following acute infection, require two-step testing (confirmatory Western blot), and may have difficulty distinguishing incident from resolved infection.[5]

In some cases, overreporting of LD may also occur. The Infectious Disease Society of America (IDSA) recommends that patients presenting with tick bites receive prophylactic treatment for LD when the local prevalence of *B. burgdorferi* infection in *I. scapularis* ticks is known to be high (greater than 20% of ticks infected).[5] In cases where providers elect to administer prophylaxis, either based on these IDSA recommendations or some other assessment of elevated risk, there is no designated ICD-9-CM code to reflect this situation. Such clinical encounters may be coded as LD cases, resulting in an overestimation of true disease burden (misclassification bias).

Because LD is a vector-borne illness, the use of entomological data to inform surveillance efforts may be beneficial. Multiple studies have demonstrated a strong positive correlation between *B. burgdorferi* infection in vector ticks (referred to as the entomological infection prevalence [EIP]) and LD.[6–8] In areas where LD is an emerging threat (e.g., along parts of the Canada–New York State border) a significant positive correlation has been demonstrated between counts of *I. scapularis* ticks and disease incidence.[9] A recent large-scale analysis of more than 300 locations confirmed a positive correlation between EIP and LD but demonstrated variability in the ability of tick data to predict LD in areas where LD is not known to be endemic.[10]

Although these studies support a potential role of tick data to supplement LD surveillance, they are limited by tick-drag sampling methods to assess vector parameters. Tick-drag sampling (or environmental sampling) is a well-established convenience sampling method to estimate local-level vector population densities. Important limitations of this technique are as follows: 1) it can collect only ticks that are living freely in the environment (not feeding or interacting with a host); 2) because of logistical considerations, it tends to sample only small geographic areas; and 3) it tends to collect a biased sample of ticks.[11] In a military context, the movement of service members throughout large training areas and between installations makes it improbable that tick drags will be conducted in all the potential areas where exposure may occur. Furthermore, military-specific occupational tasks (which often involve increased time spent outdoors and in close proximity to wooded and grassy areas) may increase

TABLE 1. Stages and selected symptoms of Lyme disease

Stage	Selected symptoms
Acute, localized	Erythema migrans ("target lesion")
	Prodromal syndrome (fatigue, malaise, fever, chills, headache, muscle ache)
Early, disseminated	Musculoskeletal, non-specific (myalgia, arthralgia)
	Erythema migrans ("target lesion")—may be multiple
	Neurologic (facial nerve palsy, meningitis [lymphocytic], encephalitis)
	Cardiac (AV blockade)
Late, disseminated	Arthrtitis
	Neurologic (peripheral neuropathy, encephalomyelitis)

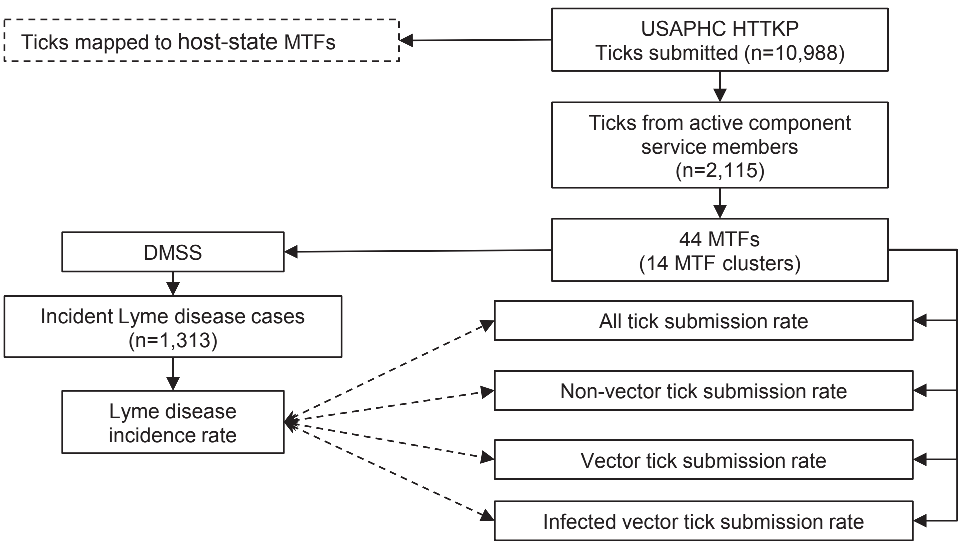
Adapted from:

1. Wright WF1, Riedel DJ, Talwani R, Gilliam BL. Diagnosis and management of Lyme disease. *Am Fam Physician*. 2012 Jun 1;85(11):1086–1093.
2. Lyme disease among U.S. military members, active and reserve component, 2001–2008. *MSMR*. 2009; 16(27):2–4.

the risk of tick exposure in ways not captured by conventional tick-drag models.[12]

Given the limitations of passive LD surveillance and the complexity involved in environmental tick sampling over large geographic areas, having installation-specific data on the ticks that are biting service members would be valuable. Moreover, understanding the relationship between these ticks and incident LD may help inform surveillance and prevention within the military. The Human Tick Test Kit Program (HTTKP) administered through the Tick-Borne Disease Laboratory of the U.S. Army Public Health Command (USAPHC) is a Department of Defense research program that identifies ticks removed from service members and their dependents and tests them for diseases transmissible to humans.[13,14] The objective of this study is to characterize the relationship between ticks removed during human feeding and voluntarily submitted to the HTTKP and the rate of incident LD among active component service members. The hypotheses are that tick removal rates are correlated with incident LD, and that the correlation is stronger for vector ticks versus any tick and is strongest for the subset of vector ticks that are proven to be infected with *B. burgdorferi*.

FIGURE 1. Schematic representation of data elements used in this analysis



USAPHC HTTKP=United States Army Public Health Command Human Tick Test Kit Program; DMSS=Defense Medical Surveillance System; MTF=military treatment facility

METHODS

This was an ecological study exploring the relationships between two independent datasets **(Figure 1)**. The Defense Medical Surveillance System (DMSS) was used to identify all active component service members in the U.S. with an incident diagnosis of LD between 1 January 2006 and 31 December 2012. The surveillance case definition was any medical encounter (inpatient or outpatient) with a diagnosis of LD (ICD-9: 088.81) in any diagnostic position, or any reportable medical event of LD. Incidence date was defined as the earliest event that satisfied these surveillance criteria. An individual could be counted only once as an incident case during the study period.

Geographic data were obtained for each case as defined by the member's unit ZIP code at the time of diagnosis. Unit ZIP codes were used as a proxy for the location of the Military Treatment Facility (MTF) closest to the patient. The sum of active component person-time (years) at each location was used to calculate MTF-specific LD incidence rates. MTFs with rates based on fewer than five cases were excluded (unstable rates), as were cases originating from MTFs outside the continental U.S.

LD incidence rates were compared annually by predetermined demographic categories. Incidence rate ratios and 95% confidence intervals were calculated.

Tick data submitted by the above identified MTFs were obtained from the USAPHC's HTTKP. *I. pacficus* ticks were not included in the analysis, which focused on *I. scapularis* in the LD endemic areas of the eastern U.S. (accounts for more than 95% of cases reported to the Centers for Disease Control and Prevention [CDC] annually).[2] MTFs that submitted fewer than five specimens during the surveillance period were excluded from further analysis. Information on species of tick and the results of polymerase chain reaction testing for *B. burgdorferi* were available within the HTTKP dataset.[15,16] Tick submissions were divided by the same denominator used to calculate LD rates to obtain MTF-specific tick submission rates.

LD rates, tick submission rates, and MTF locations (via ZIP codes) were loaded into a geographic information system, ArcGIS 10.2 (Esri, Redlands, CA), and joined to Esri-provided maps of the U.S. To ensure that de-identified data could not compromise individual patients' confidentiality, MTFs that diagnosed fewer than 10 LD cases in any surveillance year were aggregated into MTF clusters based on proximity. The geographic center of each cluster was calculated using the mean distance function in ArcGIS and mapped **(Figure 2)**. To further preserve confidentiality, Coast Guard data were aggregated with the Navy.

Tick submission and LD rates were log transformed and simple linear regressions were conducted for all relationships of interest by using two-tailed Pearson correlation coefficients. Kolmogorov-Smirnov testing was used to assess normality of the datasets after transformation. When correlations met the threshold for significance, adjustment for repeated measures sampling was performed. Both between- and within-cluster correlation coefficients were calculated to account for potential correlation among repeated measures for the same cluster.[17] An α level of 0.05 was used to determine significance for all tests performed. Analysis was conducted in SPSS 22.0 (IBM, Armonk, NY) with the assistance of the Uniformed Services University of the Health Sciences (USUHS) Biostatistics Consulting Center. The study was reviewed by the USUHS Office of Research and deemed to be exempt from the requirement for an institutional review board.

FIGURE 2. Geographic distribution of the 14 military treatment facility (MTF) clusters

MTF cluster	Individual component MTFs
A	Dover AFB/Aberdeen Proving Ground/Fort Detrick/Fort Meade/Carlisle Barracks
B	Fort Riley/Fort Sill/Fort Leavenworth/Fort Leonard Wood
C	Joint Base Langley-Eustis/Fort Monroe/Naval Station Norfolk/Fort Lee
D	Fort Monmouth/Naval Weapons Station Earle/Joint Base MDL/Picatinny Arsenal/West Point
E	Marine Corps Air Station Cherry Point/MCB Camp Lejeune/Fort Jackson
F	Fort Knox/Fort Campbell
G	Fort Bragg
H	Hanscom AFB/Fort Drum
I	Pentagon DTHC/DC Army Corps of Engineers/Joint Base Andrews
J	Naval Submarine Base New London/Naval Station Newport
K	Walter Reed NMMC
L	Fort Belvoir/Henderson Hall/Fort Myer
M	Fort Stewart/NAS Jacksonville/Eglin AFB/Redstone Arsenal
N	Fort McCoy/Camp Ripley/Wright-Patterson AFB

RESULTS

During the surveillance period, a total of 1,313 incident cases of LD were identified from 2,218,559 person-years of active component U.S. military follow-up at 14 MTF clusters. The corresponding incidence rate for the sample was 59.2 per 100,000 person-years (95% CI ± 8.3 per 100,000) during the entire surveillance period (annual mean 52.2 per 100,000; 95% CI ± 7.6). Rates were significantly higher in women and in white non-Hispanics, and there was a trend to increasing incidence with both increasing age and increasing rank **(Table 2)**. In terms of military-specific demographic variables, LD incidence was significantly higher in the Navy/Coast Guard than in the Army (rate ratio [RR]: 1.7; 95% CI 1.43–1.97), the Air Force (RR: 1.3; 95% CI 1.14–1.58), or in the Marine Corps (RR: 1.0; 95% CI 0.82–1.18).

During the same surveillance period, a total of 11,282 tick specimens were removed from patients at the 14 MTF clusters and submitted to the HTTKP; 2.7% of specimens were excluded (determined not to be ticks, consisted of tick fragments insufficient to allow for identification, or belonged to a group of infrequently encountered species). The remaining 10,988 specimens were not evenly distributed geographically **(Figure 3)**. A total of 2,115 (23.1%) of the submitted ticks were removed from active component service members. The breakdown of tick species appeared to vary by MTF cluster location, with the majority of *I. scapularis* ticks coming from more northerly latitudes **(Figure 4)**.

Including multiple measurements per MTF cluster, the overall correlation between tick submission and LD incidence was strong (0.796, p<0.01) **(Table 3)**. In fact, the log-transformed tick submission rate explained more than 63% of the variance in log-transformed LD incidence by MTF cluster **(Figure 5)**. After adjusting for repeated measures, the within-MTF-cluster correlation between annual LD incidence and both "all tick" and "non-vector

FIGURE 3. Geographic distribution of major tick species submitted to the Human Tick Test Kit Program, 2006–2012

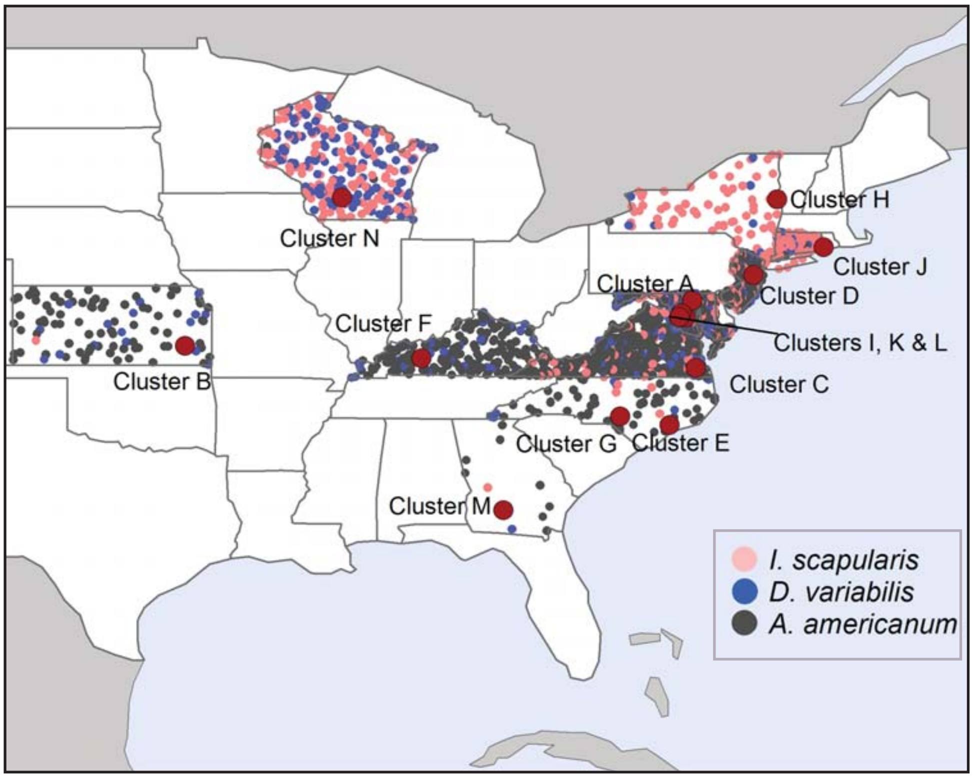


FIGURE 4. Proportional species composition of ticks found biting active component service members and submitted to the Human Tick Test Kit Program from select military treatment facility (MTF) clusters, 2006–2012

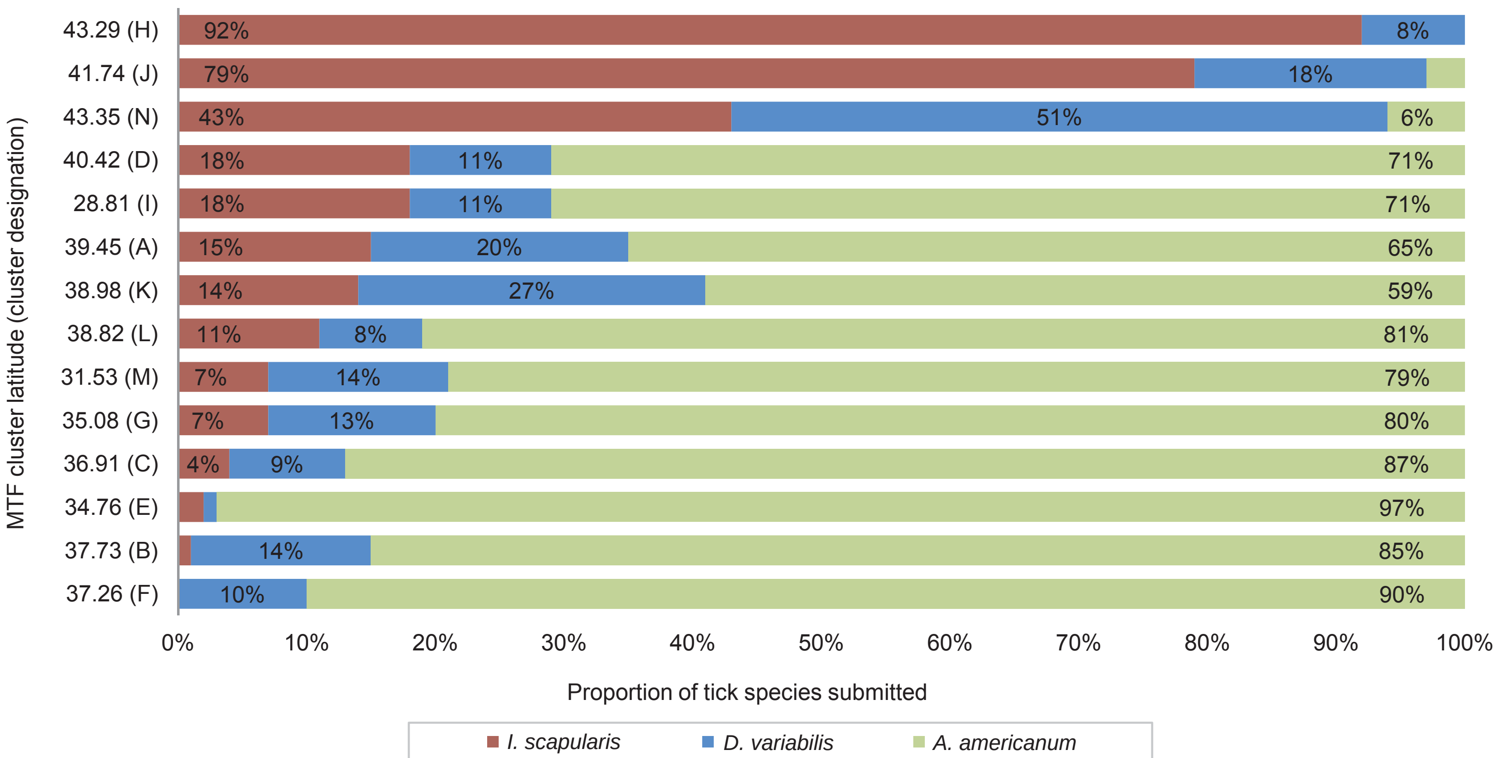


TABLE 2. Incidence rates[a] of Lyme disease (LD), active component, U.S. Armed Forces, 2006–2012

	2006		2007		2008		2009	
	LD rate (95% CI)	IRR (95% CI)	LD rate (95% CI)	IRR (95% CI)	LD rate (95% CI)	IRR (95% CI)	LD rate (95% CI)	IRR (95% CI)
Annual incidence	52.3 (44.1–60.5)	-	44.3 (36.8–51.8)	-	52.9 (44.9–60.9)	-	56.1 (47.9–64.3)	-
Age group								
<20	35.6 (13.5–57.7)	Ref	38.4 (15.7–61.1)	Ref	33.9 (12.9–54.9)	Ref	53.0 (25.2–80.7)	Ref
20–29	25.8 (18.0–33.6)	0.7 (0.4–1.4)	36.5 (27.3–45.8)	1.0 (0.5–1.8)	43.4 (33.6–53.2)	1.3 (0.7–2.5)	40.4 (31.1–49.7)	0.8 (0.4–1.4)
30–39	69.9 (51.4–88.4)	2.0 (1.0–3.9)	35.5 (22.4–48.7)	0.9 (0.5–1.9)	52.6 (36.9–68.3)	1.6 (0.8–3.1)	70.9 (52.8–89.0)	1.3 (0.8–2.4)
40+	171.2 (123.3–219.1)	4.8 (2.4–9.5)	119.6 (79.4–159.8)	3.1 (1.6-6.2)	127.8 (87.2–168.5)	3.8 (1.9–7.6)	108.7 (72.2–145.3)	2.1 (1.1–3.8)
Sex								
Female	61.2 (38.1–84.3)	1.2 (0.8–1.8)	61.3 (38.2–84.5)	1.5 (1.0–2.3)	97.4 (69.0–125.9)	2.2 (1.5–3.0)	75.3 (50.4–100.3)	1.4 (1.0–2.1)
Male	50.7 (42.0–59.5)	Ref	41.4 (33.5–49.3)	Ref	45.2 (37.1–53.3)	Ref	52.8 (44.2–61.4)	Ref
Race/ethnicity								
Black, non-Hispanic	22.9 (10.5–35.4)	0.4 (0.2–0.6)	14.5 (4.5–24.6)	0.3 (0.1–0.5)	21.1 (9.1–33.0)	0.3 (0.2–0.6)	36.8 (21.1–52.6)	0.5 (0.3–0.8)
Other	36.1 (19.4–52.8)	0.6 (0.3–0.9)	33.7 (17.7–49.7)	0.6 (0.4–1.0)	32.0 (16.8–47.2)	0.5 (0.3-0.8)	22.3 (9.7–35.0)	0.3 (0.2–0.6)
White, non-Hispanic	65.2 (53.8–76.6)	Ref	55.5 (45.1–66.0)	Ref	67.3 (56.0–78.5)	Ref	70.0 (58.7–81.4)	Ref
Service								
Army	40.8 (31.4–50.2)	Ref	33.9 (25.6–42.3)	Ref	56.3 (45.7–66.8)	Ref	57.7 (47.08–68.25)	Ref
Navy/ Coast Guard	83.2 (53.4–113.0)	2.0 (1.3–3.1)	56.6 (31.8–81.5)	1.7 (1.0–2.8)	61.7 (35.9–87.5)	1.1 (0.7–1.7)	59.7 (33.5–85.8)	1.0 (0.6–1.7)
Air Force	81.6 (55.3–107.9)	2.0 (1.4–3.0)	43.1 (23.7–62.4)	1.3 (0.8–2.2)	55.8 (33.5–78.1)	1.0 (0.6–1.5)	63.4 (39.5–87.3)	1.1 (0.7–1.7)
Marine Corps	42.0 (21.4–62.6)	1.0 (0.6–1.8)	88.3 (57.2–119.4)	2.6 (1.7–4.0)	26.6 (10.9–42.2)	0.5 (0.3–0.9)	39.7 (21.3–58.0)	0.7 (0.4–1.1)
Military occupation								
Combat-specific	36.7 (22.3–51.1)	Ref	52.7 (35.5–70.0)	Ref	50.7 (33.9–67.5)	Ref	58.5 (40.8–76.2)	Ref
Health care	63.7 (34.3–93.2)	1.7 (1.0–3.1)	59.6 (31.3–87.9)	1.1 (0.6–2.0)	74.8 (43.5–106.1)	1.5 (0.9–2.5)	56.8 (29.8–83.7)	1.0 (0.6–1.7)
Other	55.9 (45.6–66.3)	1.5 (1.0–2.4)	39.3 (30.7–48.0)	0.7 (0.5–1.1)	50.6 (41.1–60.1)	1.0 (0.7–1.5)	55.2 (45.3–65.1)	0.9 (0.7–1.3)
Rank								
Enlisted	40.6 (32.7–48.5)	Ref	33.4 (26.3–40.6)	Ref	41.6 (33.8–49.4)	Ref	44.8 (36.8–52.8)	Ref
Officer	111.0 (81.6–140.3)	2.7 (2.0–3.8)	100.1 (72.1–128.1)	3.0 (2.1–4.3)	110.6 (81.9–139.3)	2.7 (1.9–3.7)	115.4 (85.9–144.8)	2.6 (1.9–3.5)

[a]Incidence rate per 100,000 person-years
IRR=incidence rate ratio; CI=confidence interval

tick" submissions remained significant **(Table 4, Figures 6, 7)**. In this model, a 10% increase in the submission rate of ticks correlated with a 5.7% increase in LD and explained one-third of the total variation in rates (p<0.01).

The expected associations between the submission rates of *I. scapularis* ticks and LD and the submission rates of *B. burgdorferi*–infected *I. scapularis* ticks (infected vector ticks) and LD were not found to be significant.

Three independent subgroup analyses were conducted **(Table 5)**. The first subgroup analyzed were MTF clusters reporting annual EIPs 20% or greater (n=39). As previously noted, an EIP of 20% or greater is recognized by the IDSA as the threshold to initiate prophylactic treatment of patients with *I. scapularis* bites. In this subgroup, a strong correlation was noted between total tick submission rates and LD incidence explaining 53.7% of the variance in LD incidence rates. Thus, in endemic transmission zones, a 10% increase in the annual rate of tick submissions corresponded to a 7.3% increase in LD incidence **(Figure 8)**.

A second subgroup analysis (n=26) conducted for MTF clusters at risk for emerging LD infection as defined by an EIP=0% (*I. scapularis* ticks are biting active component service members but none of the ticks tested positive for *B. burgdorferi)* revealed no significant associations. The final subgroup analyzed MTF clusters that reported incident LD

TABLE 2 (cont.) Incidence rates[a] of Lyme disease (LD), active component, U.S. Armed Forces, 2006–2012

	2010		2011		2012		Total	
	LD rate (95% CI)	IRR (95% CI)	LD rate (95% CI)	IRR (95% CI)	LD rate (95% CI)	IRR (95% CI)	LD rate (95% CI)	IRR (95% CI)
Annual incidence	37.4 (30.9–44.0)	-	59.2 (50.9–67.5)	-	64.1 (55.4–72.8)	-	52.4 (49.4–55.4)	-
Age group								
<20	23.6 (4.7–42.5)	Ref	32.8 (10.1–55.5)	Ref	29.4 (7.6–51.2)	Ref	35.4 (26.9–44.0)	Ref
20–29	25.7 (18.5–33.0)	1.1 (0.5–2.6)	44.6 (35.0–54.2)	1.4 (0.7–2.8)	51.3 (40.9–61.7)	1.7 (0.8–3.8)	38.4 (34.9–41.8)	1.1 (0.8–1.4)
30–39	45.1 (30.9–59.2)	1.9 (0.8–4.5)	67.7 (50.5–85.0)	2.1 (1.0–4.3)	66.2 (49.0–83.34)	2.3 (1.0–5.0)	58.4 (52.2–64.6)	1.7 (1.3–2.1)
40+	94.7 (61.4–128.1)	4.0 (1.7–9.6)	138.1 (98.2–178.0)	4.7 (2.2–9.8)	152.7 (110.8–194.6)	5.2 (2.4–11.4)	130.1 (115.0–145.3)	3.7 (2.8–4.8)
Sex								
Female	64.2 (41.6–86.9)	2.0 (1.3–2.9)	62.2 (40.0–84.5)	1.1 (0.7–1.6)	95.6 (67.7–123.5)	1.6 (1.2–2.3)	74.0 (64.6–83.4)	1.5 (1.3–1.8)
Male	32.9 (26.2–39.5)	Ref	58.7 (49.8–67.6)	Ref	58.7 (49.7–67.7)	Ref	48.7 (45.5–51.2)	Ref
Race/ethnicity								
Black, non-Hispanic	18.5 (7.6–29.5)	0.4 (0.2–0.8)	28.9 (15.1–42.6)	0.4 (0.3–0.7)	45.2 (27.8–62.6)	0.6 (0.4–1.0)	26.9 (21.8–32.0)	0.4 (0.4–0.5)
Other	38.9 (22.6–55.1)	0.9 (0.6–1.5)	52.0 (33.4–70.6)	0.8 (0.5–1.1)	58.5 (38.9–78.2)	0.8 (0.6–1.2)	39.5 (33.2–45.9)	0.6 (0.5–0.8)
White, non-Hispanic	42.3 (33.9–50.9)	Ref	69.5 (58.4–80.7)	Ref	70.8 (59.4–82.2)	Ref	62.9 (58.8–67.0)	Ref
Service								
Army	29.2 (21.8–36.5)	Ref	53.9 (43.9–63.9)	Ref	54.7 (44.4–65.0)	Ref	46.8 (43.1–50.4)	Ref
Navy/ Coast Guard	74.2 (45.7–102.7)	2.5 (1.6–4.0)	78.8 (50.1–107.4)	1.5 (1.0–2.2)	132.7 (95.2–170.26)	2.4 (1.7–3.4)	78.4 (67.4–89.5)	1.7 (1.4–2.0)
Air Force	51.8 (30.2–73.5)	1.8 (1.1–2.9)	79.9 (53.1–106.8)	1.5 (1.0–2.2)	63.1 (39.33–87.0)	1.2 (0.8–1.8)	62.7 (53.8–71.7)	1.3 (1.1–1.6)
Marine Corps	33.3 (17.0–49.6)	1.5 (0.9–2.5)	47.9 (27.4–68.3)	0.9 (0.6–1.4)	51.6 (31.0–72.3)	0.9 (0.6–1.5)	45.9 (38.2–53.6)	1.0 (0.8–1.2)
Military occupation								
Combat-specific	31.6 (18.9–44.2)	Ref	53.9 (37.4–70.3)	Ref	69.8 (50.8–88.8)	Ref	50.6 (44.4–56.8)	Ref
Health care	50.8 (25.9–75.7)	1.6 (0.9–3.0)	61.6 (33.9–89.3)	1.1 (0.7–2.0)	69.0 (39.5–98.5)	1.0 (0.6–1.6)	62.2 (51.5–72.9)	1.2 (1.0–1.5)
Other	37.5 (29.5–45.6)	1.9 (1.3–3.0)	60.7 (50.5–70.9)	1.1 (0.8–1.6)	61.4 (51.1–71.8)	0.9 (0.6–1.2)	51.6 (48.0–55.2)	1.0 (0.9–1.2)
Rank								
Enlisted	28.9 (22.6–35.3)	Ref	49.4 (41.1–57.7)	Ref	53.3 (44.6–62.1)	Ref	41.8 (38.8–44.7)	Ref
Officer	80.5 (56.7–104.3)	2.8 (1.9–4.0)	105.8 (79.3–132.4)	2.1 (1.6–2.9)	113.0 (85.7–140.2)	2.1 (1.6–2.8)	105.1 (94.7–115.5)	2.5 (2.2–2.8)

[a]Incidence rate per 100,000 person-years
IRR=incidence rate ratio; CI=confidence interval

TABLE 3. Relationship between tick submission rates and Lyme disease incidence rates, all military treatment facility (MTF) clusters, 2006–2012

Independent variable[a]	n	Pearson correlation		Linear regression	
		Coefficient	p-value[b]	R^2	p-value
Log_{10} tick submission rate	14	0.75	<.001	0.63	<.001
Log_{10} non-vector submission rate	14	0.69	0.003	0.46	0.007
Log_{10} vector submission rate	14	0.68	0.004	0.49	0.008
Log_{10} infected vector submission rate	9[c]	0.18	0.644	-	-

[a]Rates were calculated as number of ticks submitted per 100,000 active component person-years.
[b]Two-tailed Pearson correlation
[c]Five MTF clusters did not submit any *B. burgdorferi*–infected *I. scapularis* ticks over the surveillance period.

cases but did not submit any *I. scapularis* ticks (n=18). In these areas, LD incidence appears to be independent of the rate of tick submissions.

EDITORIAL COMMENT

The mean annual LD incidence rate of 52.2 per 100,000 person-years in this study is high compared to an earlier estimate of

TABLE 4. Relationship between military treatment facility (MTF) cluster correlation - annual tick submission and annual Lyme disease incidence, 2006–2012

Independent variable[a]	n	Linear regression		Repeated sampling adjustment		
		R^2	p-value	R	R^2	p-value
Log_{10} all tick rate	98	0.56	<.01	0.51	0.326	<.01
Log_{10} non-vector tick rate	98	0.45	<.01	0.55	0.286	<.01
Log_{10} vector tick rate	80[b]	0.23	<.01	0.41	0.238	0.09
Log_{10} infected vector tick rate	53[c]	0.14	0.48	0.04	0.001	0.99

[a]Rates were calculated as number of ticks submitted per 100,000 active component person-years.
[b]18 MTF clusters did not submit an *I. scapularis* tick during the surveillance period.
[c]35 MTF clusters did not submit a *B. burgdorferi*–infected *I. scapularis* tick during the surveillance period.

TABLE 5. Subgroup analyses of the relationships between tick submission rates and Lyme disease (LD) incidence rates, 2006–2012

Independent variable[a]	n	Linear regression		Repeat sampling adjusted		
		R^2	p-value	R	R^2	p-value
Subgroup 1: MTF clusters with submitting vector ticks with EIP[b] ≥ 20% (IDSA empiric Rx threshold)						
Log_{10} tick rate	39	0.568	<.01	0.733	0.537	0.01
Log_{10} non-LD vector rate	39	0.192	0.04	0.641	0.41	0.13
Log_{10} LD vector rate	39	0.155	0.04	0.48	0.23	0.33
Log_{10} infected LD vector rate	39	0.161	0.04	0.178	0.032	0.89
Subgroup 2: MTF clusters submitting *I. scapularis* ticks with an EIP[b]=0% (vector present, agent [*B. burgdorferi*] is not)						
Log_{10} tick rate	26	0.549	<.01	0.249	0.062	0.81
Log_{10} non-LD vector rate	26	0.499	<.01	0.282	0.08	0.76
Log_{10} LD vector rate	26	0.666	<.01	0.416	0.173	0.51
Subgroup 3: MTF clusters reporting incident LD but did not submit *I. scapularis* (LD vector) ticks						
Log_{10} non-LD vector rate	18	0.415	<.01	0.535	0.286	0.18

[a]Rates were calculated as number of ticks submitted per 100,000 active component person-years.
[b]Entomological infection prevalence (EIP) was calculated as number of *B. burgdorferi* PCR (+) vector ticks per total number of vector ticks submitted.
MTF=military treatment facility; IDSA=Infectious Disease Society of America

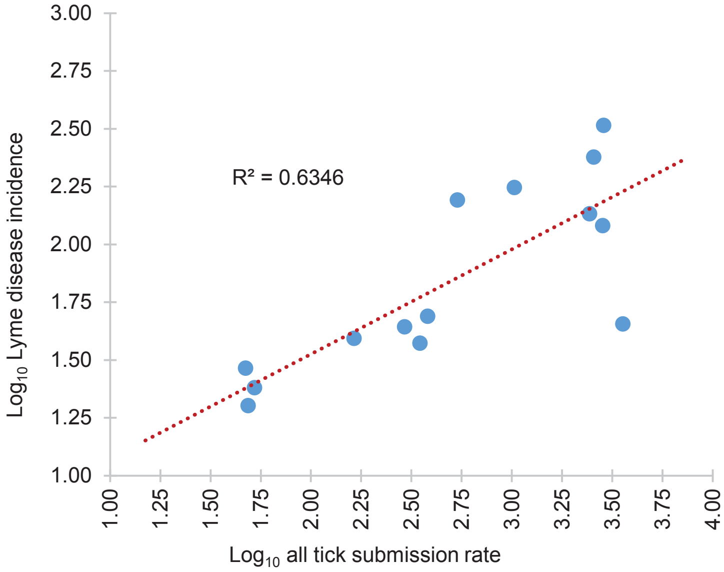
LD incidence in service members. A previously published *MSMR* report estimated that the annual rate of LD in active component service members was, at most, 16 cases per 100,000 person-years.[1] Notable differences in case definitions may explain this difference. In the *MSMR* report, two outpatient visits for LD were required within 60 days to qualify as an incident case. This case definition was more specific than the definition used in this analysis (which required only a single outpatient visit for LD to define a case). Conversely, the AFHSC definition may have missed cases that were clinically diagnosed and who either did not require or did not attend a follow-up visit. Furthermore, the AFHSC report included all active component person-time in their rate calculations, while this analysis restricted the denominator to person-time from MTFs that both diagnosed LD and submitted ticks to the HTTKP. Despite the effects of an arguably aggressive case-finding strategy and a restricted denominator, annual LD incidence rates in this study remain comfortably within the expected range of LD incidence as reported by the CDC.[18]

There was a trend toward increased LD rates with increasing age and increasing rank. From an occupational exposure perspective, this trend appeared unexpected. Greater tick exposures were predicted for younger and junior enlisted service members who were perhaps more likely to encounter ticks as a function of their occupation than their more senior colleagues. However, the peak in incidence with increasing age is consistent with the distribution of LD by age group in the civilian population.[19,20] A bimodal distribution (first peak in early adolescence) generally seen in civilian populations may not have been detected in this analysis because of the study population demographics.

The available data suggest that rates of tick submissions to the HTTKP can explain a significant amount of the annual variation in LD incidence. Notably, tick submission rates are better able to account for annual variation in disease incidence in those areas where the baseline risk of LD acquisition is greatest (EIP of 20% or greater).

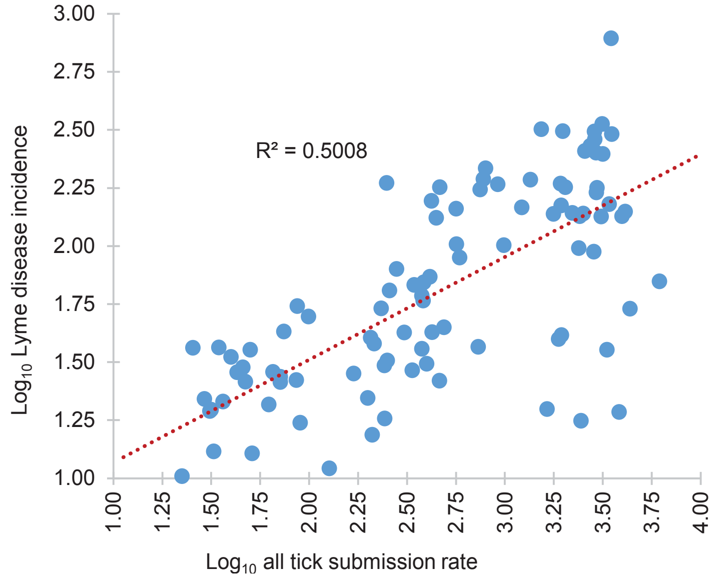
Unexpectedly, the rates of *I. scapularis*– and more specifically, *B. burgdorferi*–infected *I. scapularis* (confirmed infected vectors) were not found to be associated with LD incidence. Several potential hypotheses may explain this lack of association. First, providers may have viewed any tick bite (independent of species) as a potential vector for LD rather than risk misidentifying a tick and delaying treatment. Second, because the HTTKP is voluntary, ticks may be undersubmitted in endemic regions (providers no longer perceive a benefit to submitting them). Third, some ticks will fall off or be actively removed by patients before they seek medical care. Thus, the ticks removed from patients at a clinical encounter represent only a point-in-time (cross-sectional) sample of actual human–tick interaction. A patient may present with symptoms of LD but have only a non-LD vector attached at that particular point in time (*I. scapularis* tick may have fallen off).

FIGURE 5. Relationship between aggregated tick submission rates by military treatment facility cluster and Lyme disease incidence, active component, U.S. Armed Forces, 2006–2012



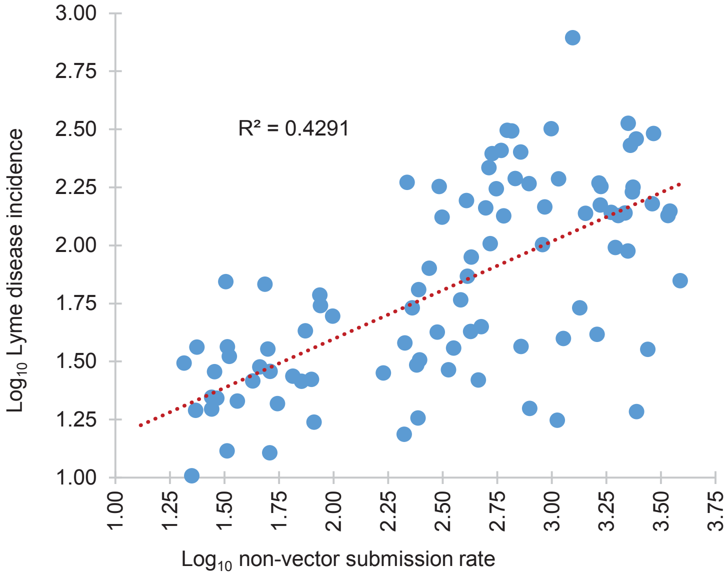
R² adjusted for repeated measures at individual military treatment facility clusters

FIGURE 6. Relationship between annual tick submission rates and Lyme disease incidence, active component, U.S. Armed Forces, 2006–2012



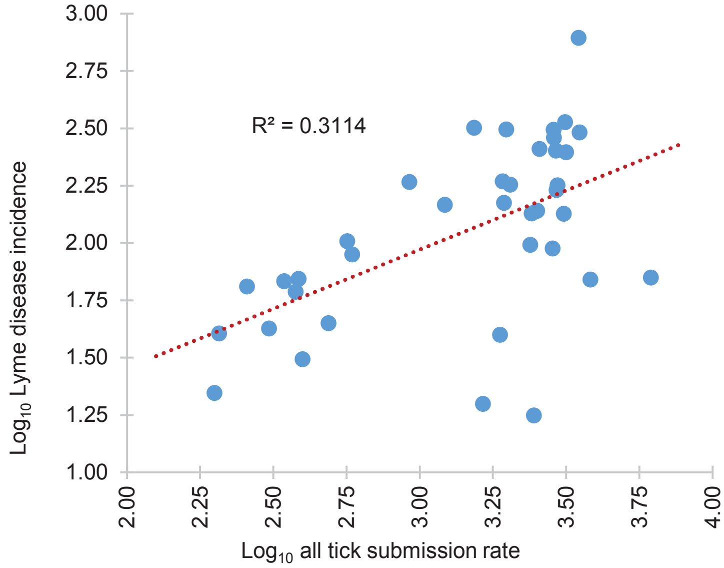
R² adjusted for repeated measures at individual military treatment facility clusters

FIGURE 7. Relationship between annual "non-vector" tick submission rates and Lyme disease incidence, active component, U.S. Armed Forces, 2006–2012



R² adjusted for repeated measures at individual military treatment facility clusters

FIGURE 8. Relationship between annual tick submission rates from military treatment facility clusters with entomological infection prevalence greater than 20% and Lyme disease incidence, active component, U.S. Armed Forces, 2006–2012



R² adjusted for repeated measures at individual military treatment facility clusters

It was also interesting that, in some MTF clusters, LD cases were diagnosed in the absence of *I. scapularis* ticks being submitted. Potential explanations for this include 1) ticks fall off or are removed; 2) late, chronic, or atypical LD may present months to years after an initial tick bite; and 3) an acute infection acquired in one location may have been diagnosed at a distant MTF. In fact, the probability of imported cases may be higher in a military population—whose members may train in an endemic area, but return for treatment to a non-endemic area—than in a comparable civilian cohort. It is possible that some encounters for tick bite may be coded as LD encounters.

This study has a number of significant limitations. First, this was an ecological study; the available tick data were not directly linked to individual patients. Second, the case definition favored enhanced case finding at the cost of higher false positive rates (sensitivity over specificity). Third, data on the precise location of tick acquisition were not available; they were assumed to have been acquired within the boundaries of an MTF's host state, and were usually aggregated into MTF clusters. This geographic aggregation is particularly problematic for those ticks submitted from MTFs located in close geographic proximity to state boundaries or to multiple MTFs, and should be acknowledged. Finally, the use of DMSS data for surveillance purposes involves accepting both under- and overreporting of cases as case detection depends on provider ICD-9-CM coding. The strengths of this analysis are as follows: 1) large numbers of both LD cases and submitted ticks; 2) expert tick identification; 3) robust testing of ticks for human pathogens; and 4) accurate mid-year location data for an otherwise highly mobile population.

LD incidence in active component service members correlates strongly with the submission rate of ticks removed from active component service members. Incorporating tick removal rates and other entomological data into existing passive surveillance systems for LD may improve the quality of these systems—particularly in areas where LD is known to be endemic. Beyond enhancing passive surveillance, disseminating the tick data already being collected by the HTTKP may have additional benefits.

First, from a direct patient care perspective, reporting regional EIP data for *I. scapularis* ticks may allow healthcare providers to more confidently follow IDSA guidelines for LD prophylaxis. Second, from a preventive medicine standpoint, informing providers in areas of potential emerging infection threat where the EIP=0% (*I. scapularis* are being found feeding on humans but have not yet tested positive for *B. burgdorferi* infection) may provide added justification for strengthening exposure prevention programs before LD becomes endemic. Third, from a public health perspective, HTTKP data may help appropriately target LD resources to MTFs where *I. scapularis* ticks are being encountered. Conversely, at locations where LD vectors are not found but ticks continue to bite service members, continuing medical education programs might reinforce that appropriate diagnostic testing for tick-borne diseases other than LD may be indicated.[21]

The lack of association between *I. scapularis* ticks and LD supports a need for improved visual tick identification guides in the ambulatory care setting. The strong association demonstrated between tick bites and LD incidence, independent of tick species, suggests that there may be uncertainty in a provider's self-assessed proficiency to correctly identify the species of ticks found biting their patients. The provision of an updated visual identification guide that includes photos of engorged female ticks (in addition to the traditional unfed female tick images) as well as up-to-date information for local resources (including local/state health departments and the HTTKP) may help address this concern.

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REFERENCES

1. Armed Forces Health Surveillance Center. Surveillance snapshot: Lyme disease among beneficiaries of the Military Health System, 2001–2012. *MSMR.* 2013;20(8):23.
2. Centers for Disease Control and Prevention. Statistics - Fast Facts: Lyme Disease. *Lyme Disease* 2014; http://www.cdc.gov/lyme/stats/index.html. Accessed on 16 January 2015.
3. Burgdorfer W, Barbour AG, Hayes SF, Benach JL, Grunwaldt E, Davis JP. Lyme disease—a tick-borne spirochetosis? *Science (New York, N.Y.).* 1982;216(4552):1317–1319.
4. Centers for Disease Control and Prevention. Lyme disease surveillance and available data. 2013. http://www.cdc/gov/lyme/stats/survafaq.html. Accessed on 14 January 2015.
5. Wormser G, Dattwyler R, Shapiro E, et al. The clinical assessment, treatment, and prevention of Lyme disease, human granulocytic anaplasmosis, and babesiosis: clinical practice guidelines by the Infectious Diseases Society of America. *Clin Infect Dis.* 2006;43:1089–1134.
6. Stafford KC, Cartter ML, Magnarelli LA, Ertel SH, Mshar PA. Temporal correlations between tick abundance and prevalence of ticks infected with *Borrelia burgdorferi* and increasing incidence of Lyme disease. *J Clin Microbio.* 1998;36(5):1240–1244.
7. Mather TN, Nicholson MC, Donnelly EF, Matyas BT. Entomologic index for human risk of Lyme disease. *Am J Epidemiol.* 1996;144(11):1066–1069.
8. Connally NP, Ginsberg HS, Mather TN. Assessing peridomestic entomological factors as predictors for Lyme disease. *J Vector Ecol.* 2006;31(2):364–370.
9. Falco RC, McKenna DF, Daniels TJ, et al. Temporal relation between *Ixodes scapularis* abundance and risk for Lyme disease associated with erythema migrans. *Am J Epidemiol.* 1999;149(8):771-776.
10. Pepin KM, Eisen RJ, Mead PS, et al. Geographic variation in the relationship between human Lyme disease incidence and density of infected host-seeking *Ixodes scapularis* nymphs in the Eastern United States. *Am J Trop Med Hyg.* 2012;86(6):1062–1071.
11. Suss J, Klaus C, Gerstengarbe FW, Werner PC. What makes ticks tick? Climate change, ticks, and tick-borne diseases. *J Travel Med.* 2008;15(1):39–45.
12. Hurt L, Dorsey KA. The geographic distribution of incident Lyme disease among active component service members stationed in the continental United States, 2004–2013. *MSMR.* 2014;21(5):13–15.
13. Armed Forces Pest Management Board. Tick-Borne Diseases: Vector Surveillance and Control. Walter Reed Army Institute of Research, 2012.
14. Stromdahl EY, Evans SR, O'Brien JJ, Gutierrez AG. Prevalence of infection in ticks submitted to the human tick test kit program of the U.S. Army Center for Health Promotion and Preventive Medicine. *J Med Entomol.* 2001;38(1):67–74.
15. Stromdahl EY, Jiang J, Vince M, Richards AL. Infrequency of *Rickettsia rickettsii* in *Dermacentor variabilis* removed from humans, with comments on the role of other human-biting ticks associated with spotted fever group Rickettsiae in the United States. *Vector Borne Zoonotic Dis.* 2011;11(7):969–977.
16. Stromdahl E, Hamer S, Jenkins S, et al. Comparison of phenology and pathogen prevalence, including infection with the *Ehrlichia muris*-like (EML) agent, of *Ixodes scapularis* removed from soldiers in the midwestern and the northeastern United States over a 15-year period (1997–2012). *Parasit Vectors.* 2014;7(1):553.
17. Bland J, Altman D. Statistics notes: Calculating correlation coefficients with repeated observations: Part 1—correlation within subjects. *BMJ.* 1995;310(6977):446.
18. Kuehn BM. CDC estimates 300,000 U.S. cases of Lyme disease annually. *JAMA.* 2013;310(11):1110.
19. Esposito S, Bosis S, Sabatini C, Tagliaferri L, Principi N. *Borrelia burgdorferi* infection and Lyme disease in children. *IJID.* 2013;17(3):e153–e158.
20. Bacon RM, Kugeler KJ, Mead PS. Surveillance for Lyme disease—United States, 1992–2006. *MMWR Surveill Summ.* 2008;57(10):1–9.
21. Stromdahl EY, Hickling GJ. Beyond Lyme: aetiology of tick-borne human diseases with emphasis on the southeastern United States. *Zoonoses Public Health.* 2012;59(Suppl 2):48–64.

Incidence and Prevalence of Diagnoses of Eye Disorders of Refraction and Accommodation, Active Component Service Members, U.S. Armed Forces, 2000–2014

Francis L. O'Donnell, MD, MPH; Stephen B. Taubman, PhD; Leslie L. Clark, PhD, MS

More than half of service members on duty in the active component of the U.S. Armed Forces in July 2014 had been previously diagnosed with at least one of the eye disorders of refraction and accommodation examined in this report. During 2000–2014, the most common diagnoses among service members, in descending order of frequency, were myopia, astigmatism, hyperopia, and presbyopia. The incidence rates for myopia were highest among those younger than 30 years and the rates for hyperopia and presbyopia were highest among those older than 39 years. Incidence rates and prevalence for all the disorders examined were higher among females than males. The methodological limitations of the analysis are discussed with respect to the generalizability of the results to the U.S. population.

The eyeball's ability to capture light waves and produce nerve signals for interpretation by the brain depends initially on refraction and accommodation. Refraction refers to the changing of the direction of light waves by the cornea and lens of the eye so that images of the objects in view are focused on the retina at the rear of the eye.[1] Accommodation refers to the eye's capacity to change the shape of the lens so as to permit clear vision of objects as their distance from the eye changes.[2]

Disorders of refraction are very common in adults but are usually susceptible to correction through the use of eyeglasses, contact lenses, or surgery. Hyperopia (or hypermetropia), often referred to as farsightedness and frequently detected early in life, means that the lens and cornea cannot focus near objects onto the retina, but can do so for distant objects. In extreme cases, even distant objects cannot be focused. Myopia (nearsightedness) means that near objects are better focused than far objects. It is the most common disorder of refraction in young adults. Astigmatism refers to abnormalities in the surface or curvature of the cornea or lens that prevent an object from being clearly focused on the retina. Less common disorders of refraction are anisometropia and aniseikonia. Anisometropia is a condition in which one eye has significantly different refractive power from the other. Aniseikonia means that one eye perceives the size of an object differently from the other eye.[3]

The most common disorder of accommodation, presbyopia, refers to an age-related deterioration in the eye's ability to focus on near objects because of diminished capacity of the lens to change its refractive power.[3] Symptoms of presbyopia are usually noticed after age 40 and affect most people by age 70. The other, much less common disorders of accommodation include a variety of types of temporary or permanent inability of the ciliary muscles to bend or straighten the lens to permit focusing on near or distant objects.[2]

The Department of Defense (DoD) has standards of visual acuity that must be met by individuals seeking to enter military service.[4] The standards aim to ensure that all service members are capable of performing all duties required by military service. In general, the standards require that vision is normal or correctable to near-normal vision in one eye and no worse than low vision in the other eye. There are more stringent requirements for certain occupational fields such as pilots. Because correctable vision can satisfy the standards, many service members have disorders of refraction and accommodation. This analysis was designed to estimate the incidence and prevalence of such disorders in members of the active component of the U.S. Armed Forces.

METHODS

The surveillance period was 1 January 2000 through 31 December 2014. Diagnoses of disorders of refraction and accommodation were ascertained from records maintained in the Defense Medical Surveillance System (DMSS) that document outpatient encounters of active component members of the Army, Navy, Air Force, Marine Corps, and Coast Guard.

Case-defining diagnoses (and related ICD-9 codes) are shown in **Table 1**. The following diagnostic categories were analyzed separately: hyperopia (ICD-9 code: 367.0), myopia (367.1), astigmatism (367.2x), anisometropia and aniseikonia together (367.3x), presbyopia (367.4), other disorders (367.5x and 367.8x together), and unspecified disorder of refraction and accommodation (367.9).

In determining incidence and prevalence, a case was defined by the presence of a diagnostic code of interest in either the first or second diagnostic position of a record of an outpatient care encounter. Such records reflect care in fixed military treatment facilities of the Military Health System (MHS) and in civilian sources of health care underwritten by the DoD.

To identify incident cases of specific disorders, individuals diagnosed with

TABLE 1. ICD-9-CM codes for disorders of refraction and accommodation

Description	ICD-9 code
Disorders of refraction and accommodation	367
Hypermetropia (far-sightedness, hyperopia)	367.0
Myopia (near-sightedness)	367.1
Astigmatism	367.2
Astigmatism, unspecified	367.20
Regular astigmatism	367.21
Irregular astigmatism	367.22
Anisometropia and aniseikonia	367.3
Anisometropia	367.31
Aniseikonia	367.32
Presbyopia	367.4
Disorders of accommodation	367.5
Paresis of accommodation (cycloplegia)	367.51
Total or complete internal ophthalmoplegia	367.52
Spasm of accommodation	367.53
Other disorders of refraction and accommodation	367.8
Transient refractive change	367.81
Other (i.e., drug-induced disorders, toxic disorders)	367.89
Unspecified disorder of refraction and accommodation	367.9

subject disorders before the start of the surveillance period were excluded. The incidence date of each case was the date of the first case-defining diagnosis during an outpatient encounter of each affected individual. A service member could be identified as an incident case of a disorder only once during the surveillance period. For incidence rate calculations, person-time at risk included all active military service prior to the dates of incident diagnoses for all cases or terminations of active service or the end of the surveillance period for all others. Total person-time at risk was calculated independently for each of the seven disorders of interest.

To identify prevalent cases of specific disorders, individuals who were diagnosed with subject disorders before the surveillance period were not excluded. During each year of the surveillance period, prevalent cases of conditions of interest were defined as individuals still serving in the active component of the Armed Forces on July 1 of the subject year who had previously been diagnosed with the conditions. In a given year, individuals could be counted as prevalent cases of more than one condition. For each year, prevalence was calculated as the ratio of the number of prevalent cases divided by the number of active component members in active service; annual prevalence was expressed as the number of prevalent cases per 100 service members.

RESULTS

Any diagnosis

From 2000 through 2014, disorders of refraction and accommodation were primary diagnoses during 4,033,681 outpatient encounters of active component members. Annual numbers of such encounters ranged from 168,792 in 2014 to 351,416 in 2004; the median number of encounters per year was 276,548 in 2007 **(Figure 1)**.

During the 15-year surveillance period, a total of 1,801,799 active component members were diagnosed with at least one disorder of refraction and accommodation. The overall incidence rate of any such diagnosis was 17.0 per 100 person-years (p-yrs) **(Table 2)**. Although females accounted for only 19% of all diagnoses, the overall incidence rate was 68% higher among females (26.4 per 100 p-yrs) than males (15.7 per 100 p-yrs) **(Figure 2)**. Among race/ethnicity groups, incidence rates were highest among Hispanics and lowest among American Indian/Alaskan Natives **(Table 2)**.

In relation to age, incidence rates of any diagnosis sharply declined from the teens through the 30s; rates were moderately higher among service members in their 40s than those in their 30s or 50s **(Table 2)**. Compared to their respective counterparts, incidence rates were higher among service members who were in the Army, enlisted, and in healthcare occupations. In general, annual incidence rates of any disorder gradually increased during the period; the lowest and highest annual rates were in 2000 (rate: 14.3 per 100 p-yrs) and 2012 (rate: 19.3 per 100 p-yrs), respectively **(Figure 2)**.

In general, annual prevalences of any disorder increased steadily during the surveillance period from 31.6 per 100 service members in 2000 to 56.4 per 100 in 2014 **(Figure 3)**. The median annual prevalence during the 15-year period was 50.8 per 100 in 2007.

Most common diagnoses

The specific disorders diagnosed most frequently were myopia, astigmatism,

FIGURE 1. Annual healthcare encounters for any diagnosis of, and for the four most common diagnoses of, disorders of refraction and accommodation, active component, U.S. Armed Forces, 2000–2014

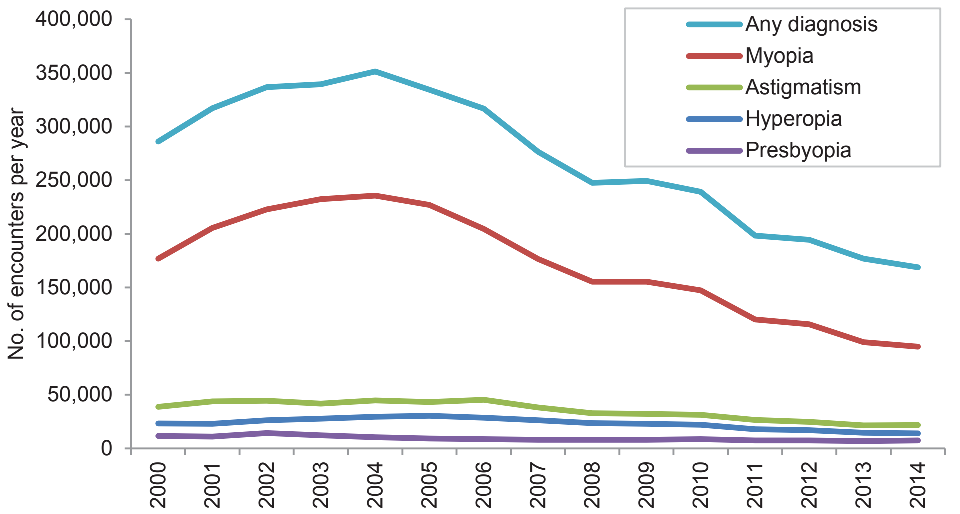


TABLE 2. Number of incident cases and overall incidence rates of disorders of refraction and accommodation, active component, U.S. Armed Forces, 2000–2014

	Any disorder of refraction/ accommodation		Myopia		Astigmatism		Hyperopia		Presbyopia		Anisometropia/ aniseikonia		Other disorders of refraction/ accommodation		Unspecified disorder of refraction/ accommodation	
	No.	Rate[a]	No.	Rate[a]	No.	Rate[a]	No.	Rate[a]	No.	Rate[a]	No.	Rate[a]	No.	Rate[a]	No.	Rate[a]
Total	1,801,799	17.0	1,232,225	8.9	1,056,130	7.6	407,069	2.2	163,987	0.8	24,038	0.1	31,257	0.1	464,638	2.5
Sex																
Male	1,461,714	15.7	989,074	8.1	856,469	7.1	330,254	2.1	138,781	0.8	18,551	0.1	23,825	0.1	381,040	2.4
Female	340,085	26.4	243,151	13.8	199,661	11.0	76,815	3.0	25,206	0.9	5,487	0.2	7,432	0.2	83,598	3.2
Race/ethnicity																
White, non-Hispanic	1,124,184	16.8	760,957	8.7	656,761	7.5	259,671	2.3	105,435	0.9	15,086	0.11	19,830	0.15	293,020	2.5
Black, non-Hispanic	287,437	15.9	192,629	8.0	172,377	7.4	67,374	2.2	29,928	0.9	3,801	0.11	5,073	0.14	77,894	2.5
Hispanic	199,775	19.1	141,031	10.1	116,887	8.2	42,502	2.2	11,961	0.6	2,696	0.12	3,315	0.15	49,502	2.6
Asian/ Pacific Islander	71,110	18.6	53,539	10.7	43,088	8.3	13,164	1.8	8,586	1.1	861	0.10	1,298	0.16	18,130	2.5
American Indian/ Alaskan Native	11,879	9.7	8,127	5.0	6,782	4.2	2,757	1.3	626	0.3	183	0.07	193	0.08	2,744	1.2
Other/unknown	107,414	21.2	75,942	11.5	60,235	8.8	21,601	2.4	7,451	0.8	1,411	0.14	1,548	0.15	23,348	2.5
Age																
≤19	407,250	46.6	254,461	23.9	127,147	10.7	34,092	2.4	609	0.0	2,158	0.1	3,706	0.25	110,679	8.2
20–24	713,736	20.1	515,896	11.3	404,227	8.2	122,214	1.9	3,594	0.1	7,266	0.1	8,811	0.13	165,047	2.7
25–29	302,421	13.9	217,930	7.4	221,133	7.5	83,723	2.1	3,231	0.1	4,754	0.1	6,460	0.14	80,918	2.0
30–34	139,989	9.2	98,016	4.8	114,895	6.1	53,262	2.1	3,068	0.1	3,121	0.1	4,822	0.15	42,945	1.6
35–39	109,689	7.9	71,640	4.0	90,913	5.6	51,465	2.4	13,566	0.6	2,930	0.1	4,408	0.17	31,565	1.4
40–44	87,857	11.9	47,220	4.6	62,045	6.9	38,659	3.3	81,569	8.0	2,162	0.1	2,005	0.13	20,086	1.5
45-49	32,907	13.2	20,848	5.9	26,733	8.8	17,063	4.2	47,249	18.6	1,102	0.2	798	0.15	9,543	2.0
50-54	6,259	8.2	5,062	5.4	7,265	9.2	5,149	4.8	9,172	14.6	407	0.3	213	0.15	3,001	2.4
55+	1,691	8.2	1,152	4.9	1,772	9.2	1,442	5.6	1,929	11.2	138	0.4	34	0.09	854	2.9
Service																
Army	727,488	19.9	468,840	9.4	394,376	7.8	140,586	2.1	61,369	0.9	8,503	0.1	9,279	0.1	280,832	4.6
Navy	393,613	15.2	267,553	7.8	243,343	7.2	105,477	2.4	44,946	0.9	6,593	0.1	11,176	0.2	69,435	1.5
Air Force	253,277	16.4	193,854	10.3	145,559	7.5	52,363	2.1	9,312	0.3	2,239	0.1	4,475	0.2	30,653	1.2
Marine Corps	385,808	15.3	273,733	8.5	248,239	7.9	97,481	2.3	42,803	0.9	6,187	0.1	5,598	0.1	74,894	1.6
Coast Guard	41,613	15.9	28,245	7.7	24,613	6.6	11,162	2.3	5,557	1.0	516	0.1	729	0.1	8,824	1.7
Rank																
Enlisted	1,585,411	17.8	1,073,117	9.2	894,183	7.6	337,537	2.2	97,737	0.6	19,009	0.1	26,020	0.1	410,637	2.6
Officer	216,388	12.9	159,108	7.2	161,947	7.9	69,532	2.4	66,250	2.3	5,029	0.1	5,237	0.2	54,001	1.8
Occupation																
Combat-specific	185,697	13.1	126,502	6.9	115,463	6.1	41,001	1.7	14,269	0.6	2,345	0.1	3,232	0.12	63,150	2.8
Armor/ motor transport	81,620	16.8	48,371	7.6	43,965	6.9	16,524	2.1	4,739	0.5	1,043	0.1	955	0.11	27,070	3.5
Pilot/aircrew	37,396	8.9	21,154	3.7	27,682	5.4	13,900	2.2	10,081	1.4	673	0.1	777	0.10	9,623	1.3
Repair/ engineer	444,917	14.3	308,254	7.5	291,938	7.1	115,873	2.2	39,548	0.7	6,325	0.1	7,971	0.13	104,938	1.9
Communica-tions/intelli-gence	348,359	15.4	246,843	8.3	232,839	7.8	89,568	2.2	40,590	0.9	5,687	0.1	7,605	0.16	97,365	2.4
Health care	150,920	19.8	109,788	10.7	103,111	10.3	41,707	2.9	23,587	1.5	2,950	0.2	3,542	0.20	45,333	3.1
Other/unknown	552,890	26.2	371,313	13.7	241,132	8.7	88,496	2.5	31,173	0.8	5,015	0.1	7,175	0.18	117,159	3.2

[a] Rate per 100 person-years

FIGURE 2. Incidence rates of any diagnosis of a disorder of refraction or accommodation, by gender, by year, active component, U.S. Armed Forces, 2000–2014

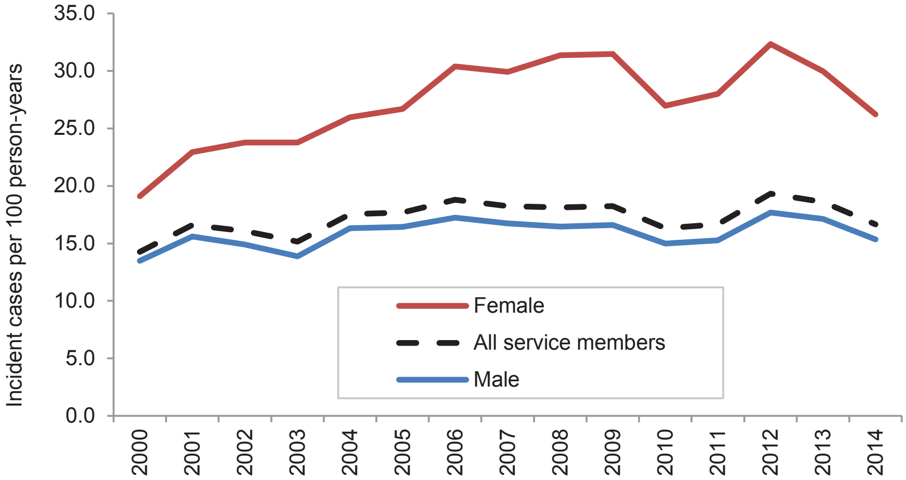
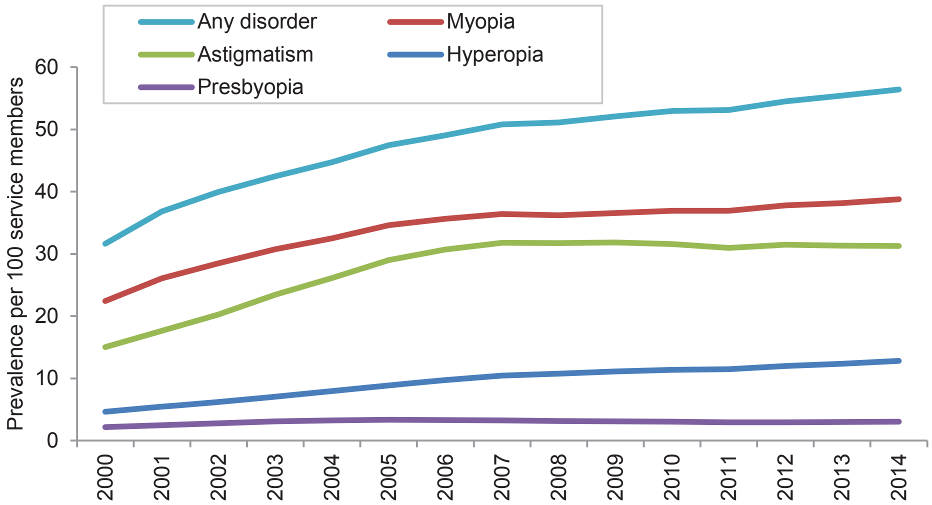


FIGURE 3. Annual prevalence of any diagnosis of, and of the four most common diagnoses of, disorders of refraction and accommodation, active component, U.S. Armed Forces, 2000–2014



hyperopia, and presbyopia **(Table 3)**. Annual incidence rates of three of the four most frequently diagnosed disorders declined during the period. Incidence rates for hyperopia increased slightly **(Figure 4)**.

Prevalence for each of the four conditions increased during the period. The prevalences of both myopia and hyperopia peaked in 2014; however, the prevalences of astigmatism and presbyopia were highest during 2009 and 2005, respectively **(Figure 3)**. The median annual prevalence of myopia for both men and women was highest in the youngest age group; for astigmatism the median annual prevalence was highest for men and women aged 30–34 years **(Table 4)**. For hyperopia and presbyopia, the prevalences were markedly higher among those older versus younger than 45 years. Astigmatism was more prevalent among men than women older than 54 years; otherwise, prevalences of the four most common disorders of refraction/accommodation were higher among women than men of all age groups **(Table 4)**.

During the period, annual numbers of healthcare encounters for refraction/accommodation disorders sharply increased from 2000 through 2002, were relatively high and stable from 2002 through 2006, and then steadily declined through 2014 **(Figure 1)**. There were fewer than half as many refraction/accommodation disorder-related health care encounters in 2014 as in 2004.

Myopia

During the surveillance period, a total of 1,232,225 service members had at least once incident diagnosis of myopia; the overall incidence rate of myopia diagnoses was 8.9 per 100 p-yrs **(Table 2)**. Most incident diagnoses (80.2%) and the highest rates affected the youngest aged (<30 years); the lowest rate was among those aged 35–39 years. Compared to other race/ethnicity groups, incidence rates of myopia diagnoses were higher among Asian/Pacific Islanders and Hispanics. Overall (unadjusted) incidence rates were also relatively high among females, members of the Air Force, and those in healthcare occupations. Annual prevalences of myopia rose steadily and rapidly from 2000 through 2006 and then continued to rise, but slowly, through 2014 **(Figure 3)**. The estimated prevalence of myopia was 77% higher in 2014 than in 2000.

Astigmatism

During the surveillance period, there were nearly as many incident diagnoses of astigmatism (n=1,056,130) as myopia; the overall incidence rate of astigmatism diagnoses was 7.6 per 100 p-yrs) **(Table 2)**. During 2003–2006, annual numbers and rates of incident diagnoses of astigmatism exceeded those of myopia. Nearly three-fourths (71.3%) of all incident diagnoses of astigmatism affected service members younger than 30 years; however, the highest age group–specific incidence rates were among the youngest (<20 years) and oldest (>44 years) service members. Overall incidence rates also were relatively high among Asian/Pacific Islanders, Hispanics, females, and those in healthcare occupations. The estimated annual prevalences of astigmatism rose steadily and rapidly from 2000 through 2007 but were remarkably stable through 2014 **(Figure 3)**. The estimated

TABLE 3. Incidence, prevalence, and outpatient encounters associated with diagnoses of disorders of refraction and accommodation, active component, U.S. Armed Forces, 2000–2014

	Total incident cases	Overall incidence rate[a]	Median annual prevalence[b]	Total no. of encounters[c]	% of all encounters[c]
Myopia	1,232,225	8.9	36.2	2,569,437	63.7
Astigmatism	1,056,130	7.6	31.0	531,436	13.2
Hyperopia	407,069	2.2	10.5	347,159	8.6
Presbyopia	163,987	0.8	3.1	139,627	3.5
Other	31,257	0.1	0.9	9,516	0.2
Anisometropia/aniseikonia	24,038	0.1	0.7	16,230	0.4
Unspecified	464,638	2.5	10.0	420,276	10.4

[a]Incident cases per 100 person-years
[b]Prevalent cases per 100 persons
[c]Restricted to encounters with diagnosis in only the first diagnostic position

FIGURE 4. Annual incidence rates of diagnoses of the four most common disorders of refraction and accommodation, active component, U.S. Armed Forces, 2000–2014

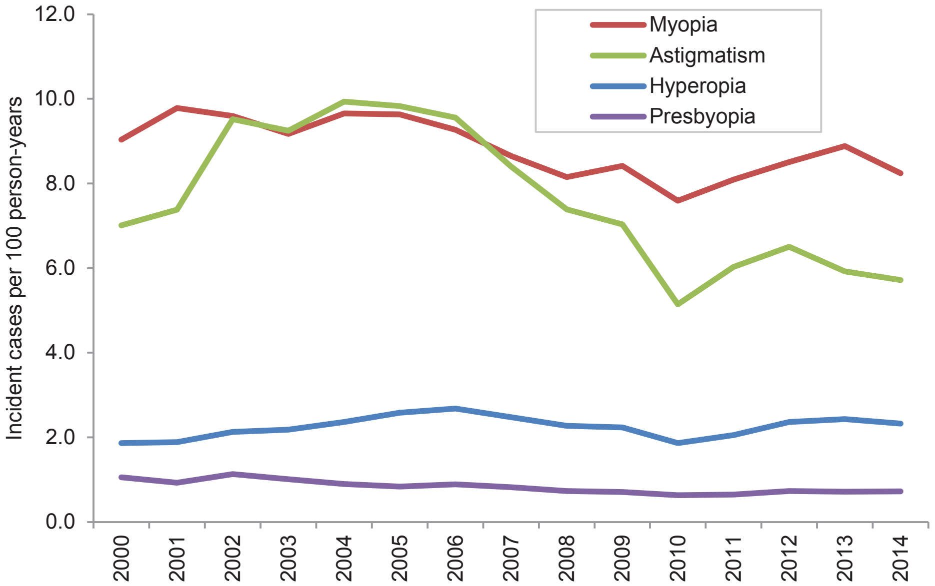


TABLE 4. Median annual prevalence[a] of the most common disorders of refraction and accommodation, by gender and age group, active component, U.S. Armed Forces, 2000–2014

	Myopia		Astigmatism		Hyperopia		Presbyopia	
Age group	Male	Female	Male	Female	Male	Female	Male	Female
≤19	46.6	51.1	29.5	35.1	7.2	11.8	0.2	0.5
20–24	30.4	44.8	25.2	35.4	7.0	11.4	0.3	0.6
25–29	35.1	46.5	31.1	38.8	10.3	12.5	0.6	0.8
30–34	37.2	47.6	34.7	40.5	13.1	14.8	1.0	1.1
35–39	31.1	42.1	30.3	37.3	12.4	15.5	1.9	3.0
40–44	28.9	40.4	25.3	33.9	12.5	14.5	15.6	23.9
45-49	32.7	43.3	28.0	36.2	14.4	16.6	32.9	41.9
50-54	30.4	36.3	27.2	32.8	16.2	20.4	33.8	40.4
55+	26.5	26.9	26.1	25.0	16.0	21.7	30.1	31.2

[a]Prevalent cases per 100 service members on 1 July

prevalence of astigmatism was approximately twice as high in 2014 as in 2000.

Hyperopia

During 2000–2014, there were 407,069 incident diagnoses of hyperopia; the overall incidence rate of hyperopia diagnoses was 2.2 per 100 p-yrs **(Table 2)**. Although 72.0% of incident diagnoses affected service members younger than 35 years, the highest rates were among those older than 39 years; among service members older than 30 years, incidence rates increased monotonically with increasing age. As with the other common disorders considered for this report, incidence rates of hyperopia diagnoses were higher among females than males, higher among those in healthcare than other occupations, and markedly lower among American Indians/Alaskan Natives than other race/ethnicity group members. Estimated annual prevalences of hyperopia steadily increased throughout the period; as such, the prevalence in 2014 (12.8 per 100) was more than 2.7 times that in 2000 (4.7 per 100) **(Figure 3)**.

Presbyopia

During the period, there were 163,987 incident diagnoses of presbyopia; the overall incidence rate was 0.8 diagnoses per 100 p-yrs **(Table 2)**. Not surprisingly, 85.3% of all affected service members were older than age 39, for whom the overall incidence rate was 10.4 cases per 100 p-yrs. Compared to their respective counterparts, overall incidence rates were higher among Asian/Pacific Islanders, officers, and those with healthcare and pilot/aircrew occupations and markedly lower among Air Force members and American Indians/Alaskan Natives. The overall incidence rate was only slightly higher among females than males. The estimated prevalence of presbyopia slowly but steadily increased during 2000–2005 and then was stable through 2014 **(Figure 3)**.

Anisometropia and aniseikonia

During the surveillance period, there were 24,038 incident diagnoses of anisometropia and aniseikonia; the overall rate was 0.11 incident diagnoses per 100 p-yrs

(Table 2). Most cases (84%) were diagnosed among service members younger than 40 years; however, overall incidence rates were markedly higher among those older than 45 years. Incidence rates were higher among females, Hispanics, officers, and healthcare personnel than their respective counterparts. The estimated prevalence slightly increased each year from 2000 through 2007 (0.72 per 100) and was low and stable through 2014 (0.71 per 100) (data not shown).

Other specific diagnoses

This category includes the five diagnoses (ICD-9: 367.51, 367.52, 367.53, 367.81, and 367.89) described in Table 1. During the period, there were 31,257 incident diagnoses of these conditions; the overall incidence rate was 0.15 per 100 p-yrs. Overall incidence rates were relatively high among the youngest aged, females, members of the Navy, and those in healthcare occupations (Table 2). As with all other conditions of interest for this report, the incident diagnosis rate (unadjusted) was lower among American Indians/Alaskan Natives than any other military or demographic subgroup of service members. The estimated prevalence of these conditions steadily increased from 2000 (0.30 per 100) through 2006 (1.40 per 100) and then steadily declined through 2014 (0.71 per 100) (data not shown).

Unspecified disorder of refraction and accommodation

During the surveillance period, there were 464,638 incident diagnoses of conditions reported as "unspecified disorders of refraction/accommodation" (ICD-9: 367.9); the overall incidence rate of such diagnoses was 2.5 per 100 p-yrs. Incident diagnosis rates (unadjusted) were relatively high among the youngest, Army members, and those in armor/motor transport occupations; incidence rates were lower among American Indians/Alaskan Natives than any other military or demographic subgroup of service members (Table 2). The use of this non-specific diagnosis code peaked in 2012 (3.4 per 100 p-yrs) and then declined through 2014 (2.7 per 100 p-yrs) (data not shown).

EDITORIAL COMMENT

Current DoD medical standards for appointment, enlistment, or induction include a set of criteria for visual acuity that specify that correction with spectacle lenses is acceptable, as long as such correction enables the individual to satisfy the stated criteria.[4] Given those entrance standards, this analysis documented that a considerable proportion of active component service members have been diagnosed with disorders of refraction and accommodation, although the ICD-9 data utilized do not permit a characterization of the severity of those disorders. The analysis found that, in 2014, the estimates of prevalence of the most common disorders were 38.8% for myopia, 31.3% for astigmatism, 12.8% for hyperopia, and 3.0% for presbyopia.

Of note are the findings that the incidence and prevalence of diagnoses of the disorders are higher among females than males; that the incidence rates of three of the four most common disorders were slightly higher among those identified as Asian/Pacific Islanders than among members of the other race/ethnicity groups; that incidence rates of diagnoses of all of the disorders were much lower among those identified as American Indian/Alaskan Natives; and that service members in the healthcare occupational category had consistently higher incidence rates than their counterparts in other occupations.

There are several methodological limitations that should be considered in interpreting the findings of this analysis. First, service members are, in many respects, not representative of the general U.S. civilian population from which they come. In particular, service members have been screened for disorders of refraction and accommodation before they join the military; individuals with severe visual problems that do not meet the DoD standards may not enter military service. As a result, the visual disorders diagnosed among service members do not include the most severe conditions. Extrapolation of the findings of this analysis to the general U.S. population should be undertaken with this limitation in mind.

Although this report shows the highest incidence rates of myopia and astigmatism to be among the youngest age groups, the finding should not be interpreted to indicate that the onset of all of these disorders took place following entry into military service. Myopia and astigmatism are known to have progressively increasing levels of prevalence from early childhood through adolescence. This study identified incident cases based on the first encounter in the MHS during which the diagnosis of interest was made. As a result, the initial identification of pre-existing visual disorders among new service members would be characterized as "incident" cases in this analysis. The finding that the median annual prevalence of both myopia and astigmatism among both males and females younger than 20 years were very high suggests that a very high proportion of these service members had myopia and astigmatism prior to entering the military. Similar caution is appropriate in interpreting the "incidence" rates for those aged 20–24 years and 25–29 years, age groups for large numbers of new accessions to the military.

As suggested by the above comments, this analysis is not able to describe the incidence or prevalence of any of the disorders among those younger than 17 years (i.e., children and most adolescents). Similarly, given the age distribution of the active component population, there are few data about the disorders among those older than 55 years, especially service members older than 62 years (the usual age limit) for military service.

This analysis was unable to characterize the severity of individual cases of the disorders examined. In addition, it did not attempt to ascertain the nature or frequency of any corrective measures or treatments, such as prescriptions for spectacles or contact lenses or corrective surgery.

REFERENCES

1. National Eye Institute of National Institutes of Health. Eye health information. https://nei.nih.gov/health/. Accessed on 23 March 2015.
2. Wikipedia. Accommodation (eye). http://en.wikipedia.org/wiki/Accommodation_(eye). Accessed on 12 February 2015.
3. Stedman's Medical Dictionary, 26th Edition. Williams & Wilkins. Baltimore. 1995.
4. Under Secretary of Defense for Personnel and Readiness. Department of Defense Instruction No. 6130.03. Medical Standards for Appointment, Enlistment, or Induction in the Military Services. April 28, 2010. Incorporating Change 1, September 13, 2011.

Update: Heat Injuries, Active Component, U.S. Armed Forces, 2014

The incidence rate of heat stroke among active component service members in 2014 was slightly higher than in 2013 but similar to the rates in 2011 and 2012. Incidence rates of heat stroke were higher among males, those younger than 20 years of age, Asian/Pacific Islanders, Marine Corps and Army members, and service members in combat-specific occupations, compared to their respective counterparts. Fewer service members were treated for "other heat injuries" in 2014 (n=1,683) than in any other year of the 5-year surveillance period. In addition, there were fewer reportable medical events for "other heat injuries" in 2014 than in any of the prior 4 years. The incidence rate of "other heat injuries" was higher among females than males and was more than 6-fold higher among recruit trainees than among other enlisted members or officers. During 2010–2014, 851 diagnoses of heat injuries were documented as having occurred among service members serving in Iraq/Afghanistan; 7.1% (n=60) of those diagnoses were for heat stroke.

Heat-related injuries are a significant threat to the health and operational effectiveness of military members and their units.[1,2] Over many decades, lessons learned during training and operations in hot environments as well as the findings of numerous research studies have resulted in doctrine, equipment, and preventive measures that can significantly reduce the adverse health effects of military activities in heat.[1–3] Although numerous effective countermeasures are available, physical exertion in hot environments still causes hundreds of injuries—some life threatening—among U.S. military members each year.[4,5]

In the U.S. Military Health System (MHS), the most serious heat-related injuries are considered notifiable medical events. Since 31 July 2009, a notifiable case of heat stroke (ICD-9: 992.0) has been defined as a "severe heat stress injury, specifically including injury to the central nervous system, characterized by central nervous system dysfunction and often accompanied by heat injury to other organs and tissue."[6,7] Notifiable cases of heat injuries other than heat stroke include "moderate to severe heat injuries associated with strenuous exercise and environmental heat stress…that require medical intervention or result in lost duty time." All heat injuries that require medical intervention or result in lost duty are reportable. Cases that do not require medical intervention or result in lost duty time are not reportable.[6,7]

This report summarizes not only reportable medical events of heat injuries but also heat injury–related hospitalizations and ambulatory visits among active component members during 2014 and compares them to the previous 4 years. Episodes of heat stroke and "other heat injuries" are summarized separately; for this analysis, "other heat injuries" includes heat exhaustion and "unspecified effects of heat."

METHODS

The surveillance period was 1 January 2010 through 31 December 2014. The surveillance population included all individuals who served in the active components of the Army, Navy, Air Force, Marine Corps, or Coast Guard at any time during the surveillance period. The Defense Medical Surveillance System (DMSS) maintains electronic records of all actively serving U.S. military members' hospitalizations and ambulatory visits in U.S. military and civilian (contracted/purchased care through the MHS) medical facilities worldwide; the DMSS also maintains records of medical encounters of service members deployed to Southwest Asia/Middle East (as documented in the Theater Medical Data Store [TMDS]). Because heat injuries represent a threat to the health of individual service members and to military training and operations, the Armed Forces require expeditious reporting of these reportable medical events through one of the service-specific electronic reporting systems; these reports are routinely transmitted and incorporated into the DMSS.

For this analysis, DMSS was searched to identify all records of medical encounters and notifiable medical event reports that included primary (first-listed) or secondary (second-listed) diagnoses of heat stroke (ICD-9: 992.0) or "other heat injury" (heat exhaustion [ICD-9: 992.3–992.5] and "unspecified effects of heat" [ICD-9: 992.9]).

This report summarizes numbers of individuals affected by documented heat injuries (i.e., incident cases) during each calendar year. To estimate numbers of incident cases per year, each individual who was affected by a heat injury event (one or more) during a year accounted for one incident case during the respective year. To classify the severity of incident cases per year, those that were associated with any heat stroke diagnosis were classified as heat stroke cases; all others were classified as "other heat injury" cases.

For surveillance purposes, a "recruit trainee" was defined as an active component service member (grades E1–E4) who was assigned to one of the Services' recruit training locations (per the individual's initial military personnel record). For this report, each service member was considered a recruit trainee for the period of time corresponding to the usual length of recruit training in his or her service. Recruit trainees were considered a separate category of enlisted service members in summaries of heat injuries by military grade overall.

Records of medical evacuations from the U.S. Central Command (CENTCOM) area of responsibility (AOR) (i.e., Iraq, Afghanistan) to a medical treatment facility outside the CENTCOM AOR were analyzed separately. Evacuations were considered case-defining if affected service members had at least one inpatient or outpatient heat injury medical encounter in a permanent military medical facility in the U.S. or Europe from 5 days before to 10 days after their evacuation dates.

RESULTS

In 2014, there were 344 incident cases of heat stroke and 1,683 incident cases of "other heat injury" among active component service members **(Table 1)**. The overall crude incidence rates of heat stroke and "other heat injury" were 0.25 and 1.22 per 1,000 person-years (p-yrs), respectively.

The annual incidence rate (unadjusted) of cases of heat stroke in 2014 was slightly higher than in 2013, and similar to rates in 2011 and 2012 **(Figure 1)**. There were more heat stroke–related reportable events and ambulatory visits in 2014 than in 2013 but fewer hospitalizations.

The annual incidence rate (unadjusted) of cases of "other heat injury" was lower in 2014 than in any other year of the surveillance period and had declined 32% since the peak in 2011 **(Figure 2)**. Most of the decline since 2011 was associated with decreases in the numbers of reportable events (44%) and ambulatory visits (32%), but even hospitalizations fell by 17% during the interval.

In 2014, subgroup-specific incidence rates of heat stroke were highest among males and service members younger than 20 years of age, Asian/Pacific Islanders, Marine Corps and Army members, recruit trainees, and combat-specific occupations **(Table 1)**. Heat stroke rates in the Marine Corps were 50% higher than in the Army; Army rates were more than 9-fold those in the other two services; the rate was 86%

TABLE 1. Incident cases[a] and incidence rates[b] of heat injury, active component, U.S. Armed Forces, 2014

	Heat stroke		Other heat injury		Total heat injury diagnoses	
	No.	Rate[b]	No.	Rate[b]	No.	Rate[b]
Total	344	0.25	1,683	1.22	2,027	1.47
Sex						
Male	314	0.27	1,410	1.21	1,724	1.47
Female	30	0.14	273	1.31	303	1.46
Age group						
<20	50	0.57	352	4.03	402	4.61
20–24	145	0.34	730	1.69	875	2.02
25–29	77	0.23	313	0.95	390	1.18
30–34	39	0.17	169	0.75	208	0.92
35–39	22	0.14	66	0.42	88	0.57
40+	11	0.07	53	0.36	64	0.44
Race/ethnicity						
White, non-Hispanic	221	0.26	1,008	1.20	1,229	1.47
Black, non-Hispanic	57	0.26	328	1.48	385	1.74
Hispanic	39	0.24	198	1.21	237	1.45
Asian/Pacific Islander	20	0.35	93	1.62	113	1.97
Other/Unknown	7	0.07	56	0.57	63	0.64
Service						
Army	205	0.40	1,023	2.01	1,228	2.41
Navy	13	0.04	92	0.29	105	0.33
Air Force	13	0.04	132	0.41	145	0.45
Marine Corps	113	0.60	427	2.25	540	2.85
Coast Guard	0	0.00	9	0.23	9	0.23
Military status						
Recruit	10	0.41	223	9.04	233	9.44
Enlisted	269	0.24	1,332	1.20	1,601	1.45
Officer	65	0.27	128	0.52	193	0.79
Military occupation						
Combat-specific	144	0.78	525	2.86	669	3.64
Armor/motor transport	8	0.15	56	1.06	64	1.21
Pilot/aircrew	2	0.04	13	0.25	15	0.29
Repair/engineering	43	0.11	258	0.63	301	0.74
Communications/intellligence	55	0.18	325	1.09	380	1.27
Health care	26	0.21	108	0.88	134	1.10
Other	66	0.25	398	1.53	464	1.78
Home of record[c]						
Midwest	56	0.23	325	1.34	381	1.57
Northeast	40	0.23	217	1.23	257	1.46
South	160	0.28	708	1.25	868	1.53
West	80	0.26	391	1.26	471	1.52
Other/unknown	8	0.10	42	0.53	50	0.63

[a]One per person per year
[b]Rate per 1,000 person-years
[c]Home of record self-reported at entry into service

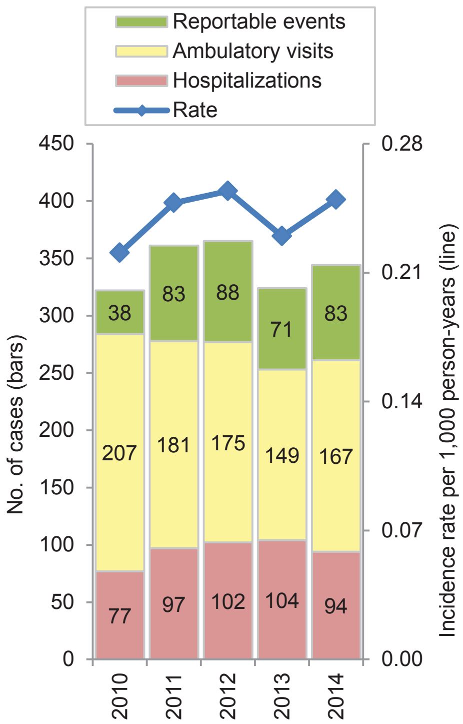


FIGURE 1. Incident cases and incidence rates of heat stroke, by source of report and year of diagnosis, active component, U.S. Armed Forces, 2010–2014

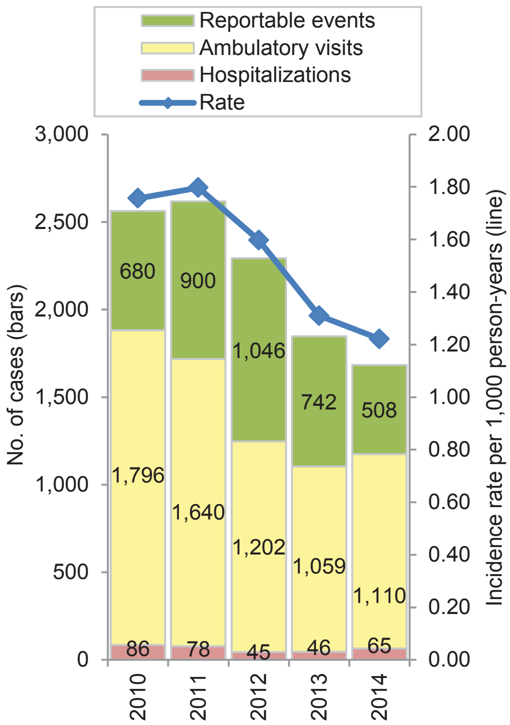


FIGURE 2. Incident cases and incidence rates of "other heat injury," by source of report and year of diagnosis, active component, U.S. Armed Forces, 2010–2014

higher among males than females. There were only 10 cases of heat stroke among recruit trainees, but their incidence rate was more than 52% higher than other enlisted members and officers.

In contrast to the heat stroke experience, the crude incidence rate of "other heat injuries" was higher among females than males **(Table 1)**. In 2014, subgroup-specific incidence rates of "other heat injuries" were highest by far among service members younger than 20 years of age, among Army and Marine Corps members, among recruit trainees, and among service members in combat-specific occupations.

Heat injuries by location

During the 5-year surveillance period, heat-related injuries were diagnosed at more than 100 military installations and geographic locations worldwide. Three Army installations accounted for 31% of all heat injuries during the period (Fort Bragg, NC [n=1,367]; Fort Benning, GA [n=1,352]; and Fort Jackson, SC [n=1,275]); four other installations accounted for an additional 15% of heat injuries (Marine Corps Base Camp Lejeune/Cherry Point, NC [n=626]; Fort Campbell, KY [n=463]; Fort Polk, LA [n=414]; and Marine Corps Recruit Depot Parris Island/Beaufort, SC [n=383]). Of the 10 installations with the most heat injuries, most are located in the southeastern U.S. **(Table 2)**.

Heat injuries in Iraq and Afghanistan

During the 5-year surveillance period, 853 heat injuries were diagnosed and treated in Iraq and Afghanistan **(Figure 3)**. Of these, 7.0% (n=60) were diagnosed as heat stroke. The numbers of heat injuries decreased in every year since 2011 and were lowest in 2014 (n=65). Deployed service members who were affected by heat injuries were most frequently male (n=683; 80.1%); white, non-Hispanic (n=516: 60.5%); aged 20–24 years (n=424; 49.7%); in the Army (n=530; 62.1%); enlisted (n=815; 95.5%); and in repair/engineering (n=229; 26.8%) or combat-specific (n=222; 26.0%) occupations **(data not shown)**. During the surveillance period, 14 service members were medically evacuated for heat injuries from Iraq or Afghanistan; 64% of the evacuations (n=9) took place in either July or August.

EDITORIAL COMMENT

This annual update of heat injuries in the active component of the U.S. Armed Forces documented that the annual incidence rates of diagnoses of heat stroke have been relatively stable during the past 5 years, but the incidence rates of diagnoses of other heat injuries have declined by nearly one-third since 2011. In the separate analysis of heat injuries diagnosed and treated in Iraq and Afghanistan during 2010–2014, the sharp decrease in the annual numbers of incident cases of heat

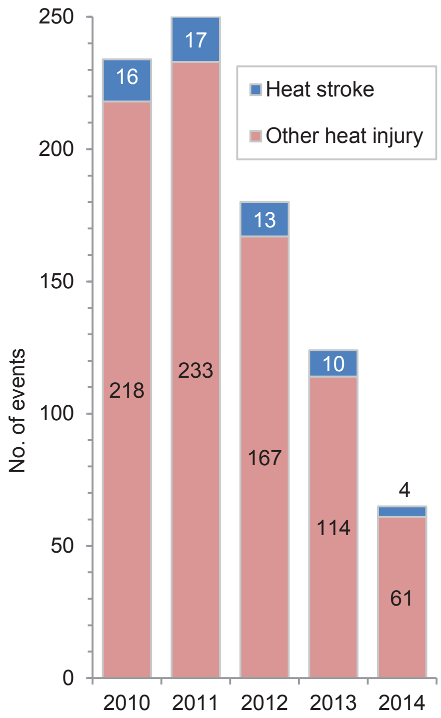
TABLE 2. Heat injuries[a] by location of diagnosis/report, active component, U.S. Armed Forces, 2010–2014

Location of diagnosis	No.	% total
Fort Bragg, NC	1,367	10.7
Fort Benning, GA	1,352	10.6
Fort Jackson, SC	1,275	10.0
MCB Camp Lejeune/ Cherry Point, NC	626	4.9
Fort Campbell, KY	463	3.6
Fort Polk, LA	414	3.3
MCRD Parris Island/ Beaufort, SC	383	3.0
MCB Quantico, VA	257	2.0
Fort Hood, TX	254	2.0
MCB Camp Pendleton, CA	234	1.8
Okinawa, Japan	230	1.8
NMC San Diego, CA	228	1.8
Fort Stewart, GA	209	1.6
Fort Sill, OK	198	1.6
JBSA-Lackland, TX	174	1.4
All other locations	5,055	39.7
Total	12,719	100.0

[a]One heat injury per person per year

MCB=Marine Corps Base; MCRD=Marine Corps Recruit Depot; NMC=Naval Medical Center; JBSA=Joint Base San Antonio

FIGURE 3. Numbers of heat injuries[a] reported from Iraq/Afghanistan, 2010–2014



[a]One per person per 60 days

injuries is consistent with the declining numbers of U.S. forces in those two countries in the past 5 years.

The results of this update should be interpreted with consideration of its limitations. Similar heat-related clinical illnesses are likely managed differently and reported with different diagnostic codes at different locations and in different clinical settings. Such differences undermine the validity of direct comparisons of rates of nominal heat stroke and "other heat injury" events across locations and settings. Also, heat injuries during training exercises and deployments that are treated in field medical facilities are not completely ascertained as cases for this report. It should also be noted that the guidelines for mandatory reporting of heat injuries (re-titled "heat illness") were modified in the 2012 revision of the guidelines for reportable medical events.[6,7] It is possible that the numbers of reports of heat injuries might have been affected by the change in guidelines. To compensate for such possible variation in reporting, the analysis for this update, as in previous years, included cases identified in DMSS records of ambulatory care and hospitalizations utilizing a consistent set of ICD-9 codes for the entire surveillance period. The data indicate that a sizable proportion of cases identified through DMSS records did not prompt mandatory reports through the reporting system.

In spite of its limitations, this report documents that heat injuries are still a significant threat to the health of U.S. military members and the effectiveness of military operations. Of all military members, the youngest and most inexperienced Marines and soldiers (particularly those training at installations in the southeastern U.S.) are at highest risk of heat injuries—including heat stroke, exertional hyponatremia, and exertional rhabdomyolysis (see the other articles in this issue of the *MSMR*).

Commanders, small unit leaders, training cadre, and supporting medical personnel—particularly at recruit training centers and installations with large combat troop populations—must ensure that military members whom they supervise and support are informed regarding risks, preventive countermeasures (e.g., water consumption), early signs and symptoms, and first-responder actions related to heat injuries.[1–3] Leaders should be aware of the dangers of insufficient hydration on the one hand and excessive water intake on the other; they must have detailed knowledge of, and rigidly enforce countermeasures against, all types of heat injuries.

Policies, guidance, and other information related to heat injury prevention and treatment among U.S. military members are available online at: http://phc.amedd.army.mil/topics/discond/hipss/Pages/HeatinjuryPrevention.aspx and http://www.marines.mil/Portals/59/Publications/MCO%206200.1E%20W%20CH%201.pdf.

REFERENCES

1. Goldman RF. Ch 1: Introduction to heat-related problems in military operations. In *Textbook of Military Medicine: Medical Aspects of Harsh Environments (Volume 1)*. Borden Institute, Office of the Surgeon General, U.S. Army. Washington, DC. 2001:3–49.
2. Sonna LA. Ch 9: Practical medical aspects of military operations in the heat. In *Textbook of Military Medicine: Medical Aspects of Harsh Environments (Volume 1)*. Borden Institute, Office of the Surgeon General, U.S. Army. Washington, DC. 2001:293–309.
3. Technical Bulletin Medical 507/AFPAM 48-152(I): Heat stress control and heat casualty management. Headquarters, Departments of the Army and Air Force. Washington, DC. March 7, 2003.
4. Carter R 3rd, Cheuvront SN, Williams JO, et al. Epidemiology of hospitalizations and deaths from heat illness in soldiers. *Med Sci Sports Exerc.* 2005; 37(8):1338–1344.
5. Armed Forces Health Surveillance Center. Update: heat injuries, active component, U.S. Armed Forces, 2013. *MSMR*. 2014; 21(3):10–13.
6. Armed Forces Health Surveillance Center. Tri-Service Reportable Events Guidelines and Case Definitions, June 2009. Found at: https://www.afhsc.mil/documents/pubs/documents/TriService_CaseDefDocs/June09TriServGuide.pdf. Accessed on 23 March 2015.
7. Armed Forces Health Surveillance Center. Armed Forces Reportable Events Guidelines and Case Definitions, March 2012. Found at: https://www.afhsc.mil/documents/pubs/documents/TriService_CaseDefDocs/ArmorcesGuidlinesFinal14Mar12.pdf. Accessed on 23 March 2015.

Surveillance Snapshot: The Geographic Distribution of Heat Injuries Among Active Component Service Members, U.S. Armed Forces, 2010–2014

FIGURE 1. Five-year average incidence rates per 100,000 person-years of heat stroke by unit location,[a] active component, U.S. Armed Forces, 2010–2014

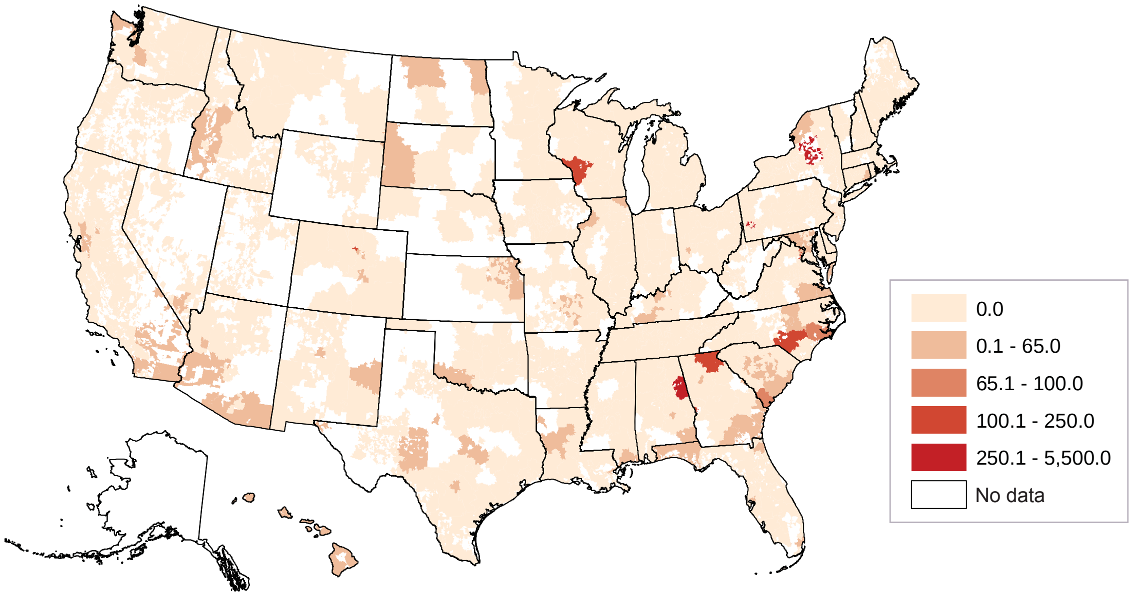
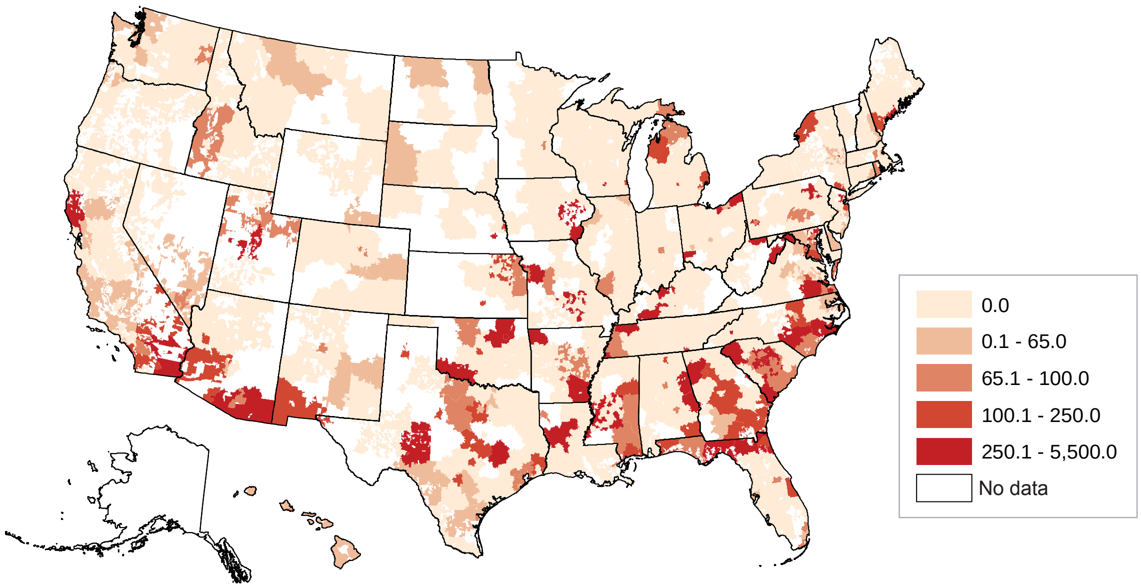


FIGURE 2. Five-year average incidence rates per 100,000 person-years of other heat injuries by unit location,[a] active component, U.S. Armed Forces, 2010–2014



[a]Incident cases and incidence rates were derived using the methodology previously described (page 17: Update: heat injuries). The geographic location of each case was defined as the service member's unit three-digit ZIP code at the time of incident diagnosis. Incidence rates were computed by dividing the number of incident cases by the sum of the active component person-time in years for each three-digit unit ZIP code; then a 5-year average per unit ZIP was calculated. The 5-year average and associated three-digit unit ZIP were loaded into Arc-GIS (Esri, Redlands, CA), and joined to an Esri-provided map of U.S. three-digit ZIP codes.

Update: Exertional Rhabdomyolysis, Active Component, U.S. Armed Forces, 2010–2014

Among active component U.S. service members in 2014, there were 403 incident episodes of rhabdomyolysis likely due to physical exertion or heat stress ("exertional rhabdomyolysis"). The annual incidence rates of exertional rhabdomyolysis increased nearly 50% during 2010–2014. In 2014, the highest incidence rates occurred in service members who were male; younger than 20 years of age; black, non-Hispanic; members of the Marine Corps and Army; recruit trainees; and in combat-specific occupations. Incidence rates were higher among service members with homes of record from the Northeast compared to other U.S. regions. Most cases of exertional rhabdomyolysis were diagnosed at installations that support basic combat/recruit training or major ground combat units of the Army or Marine Corps. Medical care providers should consider exertional rhabdomyolysis in the differential diagnosis when service members (particularly recruits) present with muscular pain and swelling, limited range of motion, or the excretion of dark urine (e.g., myoglobinuria) after strenuous physical activity, particularly in hot, humid weather.

Rhabdomyolysis refers to the rapid breakdown of skeletal muscle cells, a process most often recognized by the appearance in the urine of brown-colored myoglobin following its release from damaged muscle cells into the bloodstream. Myoglobin is toxic to the tubular cells of the kidney and can induce renal failure. In U.S. military members, rhabdomyolysis is a significant threat during physical exertion, particularly under heat stress. Each year, the *MSMR* summarizes numbers, rates, trends, risk factors, and locations of occurrences of exertional heat injuries, including exertional rhabdomyolysis. This report includes the data for the years 2010–2014. More detailed information about the definition, causes, and prevention of exertional rhabdomyolysis can be found in previous issues of the *MSMR*.[1]

METHODS

The surveillance period was 1 January 2010 through 31 December 2014. The surveillance population included all individuals who served in an active component of the U.S. Armed Forces at any time during the surveillance period. The Defense Medical Surveillance System (DMSS) maintains electronic records of all actively serving U.S. military members' hospitalizations and ambulatory visits in U.S. military and civilian (contracted or purchased care through the Military Health System) medical facilities worldwide. The DMSS also maintains records of medical encounters of service members deployed to Southwest Asia/Middle East (as documented in the Theater Medical Data Store).

For this analysis, the DMSS was searched for records of healthcare encounters (inpatient or outpatient) associated with diagnoses related to the occurrence of exertional rhabdomyolysis. For surveillance purposes, a case of "exertional rhabdomyolysis" was defined as a hospitalization or ambulatory visit with a discharge diagnosis in any position of either "rhabdomyolysis" (ICD-9: 728.88) or "myoglobinuria" (ICD-9: 791.3) plus a diagnosis in any position of one of the following: "volume depletion (dehydration)" (ICD-9: 276.5x), "effects of heat" (ICD-9: 992.0–992.9), "effects of thirst (deprivation of water)" (ICD-9: 994.3), "exhaustion due to exposure" (ICD-9: 994.4), or "exhaustion due to excessive exertion (overexertion)" (ICD-9: 994.5). Each individual could be included as a case only once per calendar year.

To exclude cases of rhabdomyolysis that were secondary to traumatic injuries, intoxications, or adverse drug reactions, medical encounters with diagnoses in any position of "injury, poisoning, toxic effects" (ICD-9: 800–999, except "sprains and strains of joints and adjacent muscles" [ICD-9: 992.0–992.9, 994.3–994.5, and 840–848]) were not considered indicative of "exertional rhabdomyolysis."

For surveillance purposes, a "recruit trainee" was defined as an active component member in an enlisted grade of E1–E4 who was assigned to one of the Services' recruit training locations (per the individual's initial military personnel record). For this report, each service member was considered a recruit trainee for the period of time corresponding to the usual length of recruit training in his or her service. Recruit trainees were considered a separate category of enlisted service members in summaries of rhabdomyolysis cases by military grade overall.

Records of medical evacuations from the U.S. Central Command (CENTCOM) area of responsibility (AOR) (e.g., Iraq, Afghanistan) to a medical treatment facility outside the CENTCOM AOR were analyzed separately. Evacuations were considered case-defining if affected service members met the above criteria in a permanent military medical facility in the U.S. or Europe from 5 days before to 10 days after their evacuation dates.

RESULTS

In 2014, there were 403 incident diagnoses of rhabdomyolysis likely associated with physical exertion and/or heat stress ("exertional rhabdomyolysis") **(Table 1)**. The crude incidence rate was 29.3 per 100,000 person-years (p-yrs).

In 2014, relative to their respective counterparts, the highest incidence rates of exertional rhabdomyolysis affected service members who were male; younger than 20 years of age; and black, non-Hispanic **(Table 1)**. Compared to other race/ethnicity groups, the incidence rate of exertional rhabdomyolysis among black, non-Hispanics was highest overall during the period and in every year except 2013 when the highest rate occurred in Asian/Pacific Islanders **(data not shown)**. Subgroup-specific incidence rates were highest among service members in the Marine Corps and Army, in combat-specific occupations, and those with homes of record from the Northeast region of the U.S. Of note, incidence rates among recruit trainees were more than four times those among other enlisted members and officers.

The annual rates of exertional rhabdomyolysis increased more than 51% from 2010 to 2011 (19.5 and 29.5 per 100,000 p-yrs, respectively) **(Figure 1)**. The annual numbers and rates of incident diagnoses of exertional rhabdomyolysis decreased slightly in 2012 and 2013, then increased again to 29.5 per 100,000 p-yrs in 2014.

In 2014, 75% of all service members who were diagnosed with exertional rhabdomyolysis were in either the Army (n=180) or the Marine Corps (n=123) **(Table 1)**. Annual incidence rates were much higher in the Marine Corps than any of the other services during every year of the surveillance period **(Figure 2)**. The annual incidence rates in all Services except the Navy increased from 2013 to 2014. During the 5-year surveillance period, most cases (70%) occurred during May–September **(Figure 3)**.

Rhabdomyolysis by location

During the 5-year surveillance period, the medical treatment facilities at nine installations diagnosed at least 50 cases each and, together, nearly 50% of all cases **(Table 2)**. Of these installations, four provide support to recruit/basic combat training centers (Marine Corps Recruit Depot

TABLE 1. Incident cases and incidence rates[a] of exertional rhabdomyolysis, active component, U.S. Armed Forces, 2014

	Hospitalizations		Ambulatory visits		Total	
	No.	Rate[a]	No.	Rate[a]	No.	Rate[a]
Total	184	13.4	219	15.9	403	29.3
Gender						
Male	171	14.6	203	17.4	374	32.0
Female	13	6.3	16	7.7	29	14.0
Age group						
<20	24	21.2	33	29.2	57	50.5
20–24	68	15.4	84	19.0	152	34.4
25–29	41	12.7	55	17.1	96	29.8
30–34	36	16.5	23	10.6	59	27.1
35–39	10	6.7	15	10.1	25	16.8
40+	5	3.7	9	6.7	14	10.5
Race/ethnicity						
White, non-Hispanic	102	12.2	130	15.5	232	27.7
Black, non-Hispanic	39	17.6	56	25.3	95	43.0
Hispanic	20	12.2	17	10.4	37	22.6
Asian/Pacific Islander	9	15.7	7	12.2	16	27.8
Other/unknown	14	14.3	9	9.2	23	23.5
Service						
Army	88	17.3	92	18.1	180	35.4
Navy	15	4.7	18	5.6	33	10.3
Air Force	31	9.7	33	10.3	64	20.0
Marine Corps	48	25.3	75	39.6	123	64.9
Coast Guard	2	5.1	1	2.5	3	7.6
Military status						
Recruit	15	60.8	18	72.9	33	133.7
Enlisted	139	12.5	178	16.1	317	28.6
Officer	30	12.2	23	9.4	53	21.6
Military occupation						
Combat-specific	44	24.0	51	27.8	95	51.7
Armor/motor transport	4	7.6	6	11.3	10	18.9
Pilot/air crew	2	3.9	5	9.7	7	13.6
Repair/engineering	37	9.1	37	9.1	74	18.2
Communications/intelligence	34	11.4	36	12.0	70	23.4
Health care	19	15.5	18	14.7	37	30.3
Other	44	16.9	66	25.3	110	42.2
Home of record[b]						
Midwest	23	9.5	40	16.4	63	25.9
Northeast	26	14.7	42	23.8	68	38.5
South	83	14.6	99	17.4	182	32.1
West	43	13.8	29	9.3	72	23.2
Other/unknown	9	11.3	9	11.3	18	22.6

[a]Rate per 100,000 person-years
[b]Home of record self-reported at entry into service

FIGURE 1. Incident cases and incidence rates of exertional rhabdomyolysis by clinical setting, active component, U.S. Armed Forces, 2010–2014

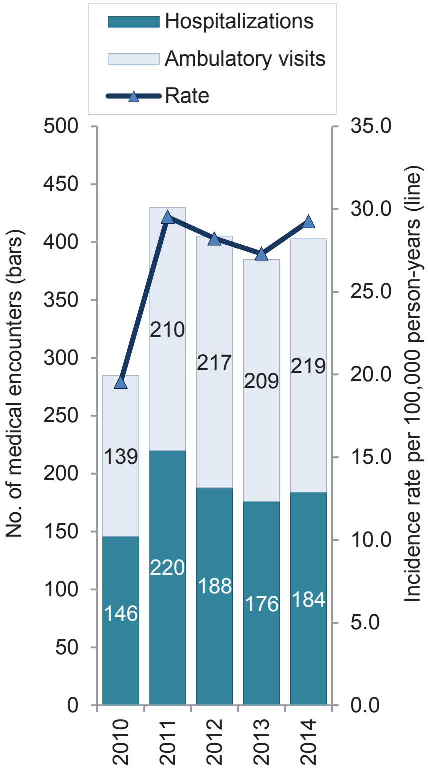


FIGURE 2. Incidence rates of exertional rhabdomyolysis by Service, active component, U.S. Armed Forces, 2010–2014

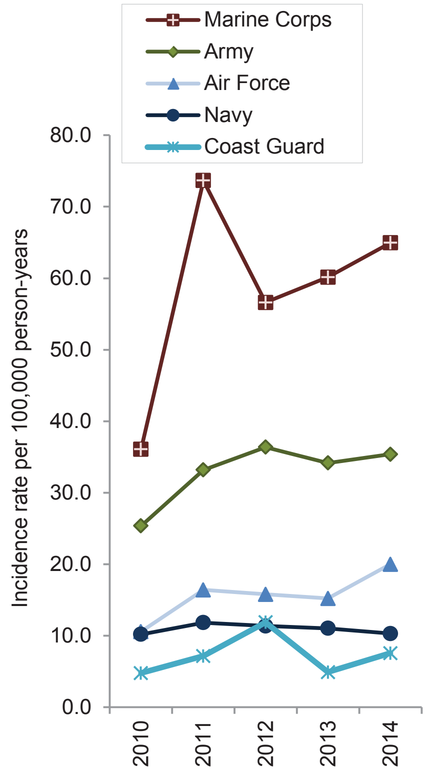
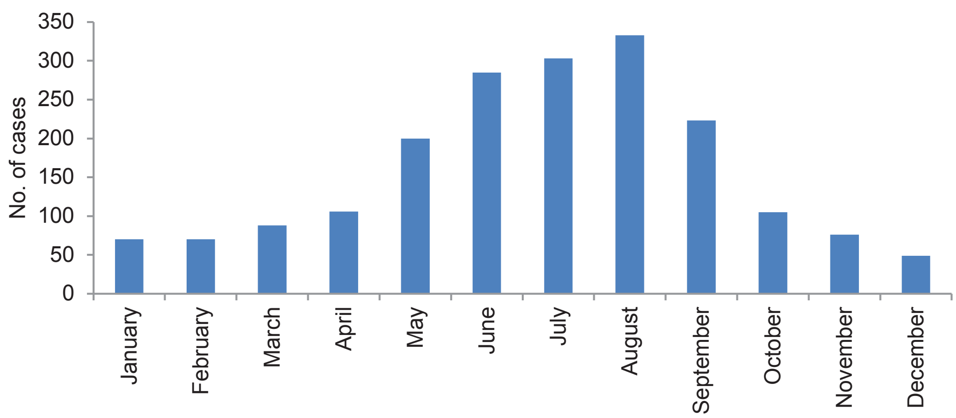


FIGURE 3. Incident cases of exertional rhabdomyolysis by month, active component, U.S. Armed Forces, 2010–2014



[MCRD] Parris Island/Beaufort, SC; Fort Benning, GA; Fort Jackson, SC; and Joint Base San Antonio–Lackland, TX). In addition, five installations support large combat troop populations (Fort Bragg, NC; Marine Corps Base [MCB] Camp Pendleton, CA; MCB Camp Lejeune/Cherry Point, NC; Fort Hood, TX, and Fort Shafter, HI). The most cases overall (together accounting for 25% of all cases) were diagnosed at Fort Bragg, NC (n=278) and MCRD Parris Island/Beaufort, SC (n=196).

Rhabdomyolysis in Iraq and Afghanistan

During the 5-year surveillance period, there were 18 incident cases of exertional rhabdomyolysis diagnosed and treated in Iraq/Afghanistan **(data not shown)**. Deployed service members who were affected by exertional rhabdomyolysis were most frequently male (n=17; 94.4%); white; or black, non-Hispanic (n=8; 44.4% and n=7; 38.9%, respectively); aged 20–24 years (n=7; 38.9%); in the Army (n=13; 72.2%); enlisted (n=16; 88.9%); and in combat-specific occupations (n=10; 55.6%). Three active component service members were medically evacuated from Iraq/Afghanistan for exertional rhabdomyolysis; two occurred in September and one in July **(data not shown)**.

EDITORIAL COMMENT

This report documents a modest increase in the annual rates of diagnoses of exertional rhabdomyolysis among active component members of the U.S. military in 2014 compared to 2012 and 2013. Exertional rhabdomyolysis continued to occur most frequently from late spring through early fall at installations that support basic combat/recruit training or major Army or Marine Corps combat units.

The risks of heat injuries, including exertional rhabdomyolysis, are increased among individuals who suddenly increase overall levels of physical activity, recruits who are not physically fit when they begin training, and recruits from relatively cool and dry climates who may not be acclimated to the high heat and humidity at training camps in the summer.[2,3] Soldiers and Marines in combat units often conduct rigorous unit physical training, personal fitness training, and field training exercises regardless of weather conditions. Thus, it is not surprising that incidence rates of exertional rhabdomyolysis are highest among recruit trainees and service members from the northeastern U.S. and that recruit camps and installations with large ground combat units account for most of these cases.

The annual incidence rates in black, non-Hispanic service members were

TABLE 2. Incident cases of exertional rhabdomyolysis by installation (with at least 30 cases during the period), active component, U.S. Armed Forces, 2010–2014

Location of diagnosis	No.	% total
Fort Bragg, NC	278	14.6
MCRD Parris Island/ Beaufort, SC	196	10.3
MCB Camp Pendleton, CA	112	5.9
MCB Camp Lejeune/ Cherry Pt, NC	74	3.9
Fort Benning, GA	61	3.2
Fort Hood, TX	59	3.1
Fort Jackson, SC	58	3.0
Fort Shafter, HI	56	2.9
JBSA-Lackland, TX	53	2.8
Navy Research Laboratory, DC	40	2.1
Fort Bliss, TX	39	2.0
Fort Campbell, KY	38	2.0
Fort Belvoir, VA	34	1.8
NMC San Diego, CA	32	1.7
Fort Stewart, GA	32	1.7
Other locations	746	39.1
Total	1,908	100.0

MCRD=Marine Corps Recruit Depot; MCB=Marine Corps Base; JBSA=Joint Base San Antonio; NMC=Naval Medical Center

consistently higher than the rates among members of other race/ethnicity subgroups in 2014 and in previous years. This observation has been attributed, at least in part, to an increased risk of exertional rhabdomyolysis among individuals with sickle cell trait.[4–6] In 2013, however, the rate among Asian/Pacific Islanders was the highest of all race/ethnicity groups. Although the annual incidence rates for this group have been on the increase since 2009, the reasons for such a trend are unknown. Supervisors at all levels should assure that guidelines to prevent heat injuries are consistently implemented and should be vigilant for early signs of exertional heat injuries, including rhabdomyolysis, among all service members.

The findings of this report should be interpreted with consideration of its limitations. A diagnosis of "rhabdomyolysis" alone does not indicate the cause. Ascertainment of the probable causes of cases of exertional rhabdomyolysis was attempted by using a combination of ICD-9 diagnostic codes related to rhabdomyolysis with additional codes indicative of the effects of exertion, heat, or dehydration. Furthermore, other ICD-9 codes were used to exclude cases of rhabdomyolysis that were secondary to trauma, intoxication, or adverse drug reactions.

The measures that are effective at preventing exertional heat injuries in general apply to the prevention of exertional rhabdomyolysis. In the military training setting, the intensity and duration of exercise and adherence to prescribed work-rest cycles during strenuous physical activities should be adapted not only to ambient weather conditions but also to the fitness levels of participants in strenuous activities. The physical activities of overweight and/or previously sedentary new recruits should increase gradually and be closely monitored. Water intake should comply with current guidelines and be closely supervised. Strenuous activities during relatively cool mornings following days of high heat stress should be particularly closely monitored; in the past, such situations have been associated with increased risk of exertional heat injuries (including rhabdomyolysis).[7] Commanders and supervisors at all levels should be aware of and alert for early signs of exertional heat injuries and should aggressively intervene when dangerous conditions, activities, or suspicious illnesses are detected.

Finally, medical care providers should consider exertional rhabdomyolysis in the differential diagnosis when service members (particularly recruits) present with muscular pain or swelling, limited range of motion, or the excretion of dark urine (possibly due to myoglobinuria) after strenuous physical activity, particularly in hot, humid weather.

REFERENCES

1. Armed Forces Health Surveillance Center. Update: Exertional rhabdomyolysis among active component members. *MSMR*. 2009;16(3):10–13.
2. Bedno SA, Li Y, Cowan DN, et al. Exertional heat illness among overweight U.S. Army recruits in basic training. *Aviat Space Environ Med*. 2010;81(2):107–111.
3. Carter III R, Cheuvront SN, Williams JO, et al. Epidemiology of hospitalizations and deaths from heat illness in soldiers. *Med Sci Sports Exerc*. 2005;37(8):1338–1344.
4. Makaryus JN, Catanzaro JN, Katona KC. Exertional rhabdomyolysis and renal failure in patients with sickle cell trait: is it time to change our approach? *Hematology*. 2007;12(4):349–352.
5. Ferster K, Eichner ER. Exertional sickling deaths in Army recruits with sickle cell trait. *Mil Med*. 2012;177(1):56–59.
6. Gardner JW, Kark JA. Fatal rhabdomyolysis presenting as mild heat illness in military training. *Mil Med*. 1994;159(2):160–163.
7. Kark JA, Burr PQ, Wenger CB, Gastaldo E, Gardner JW. Exertional heat illness in Marine Corps recruit training. *Aviat Space Environ Med*.1996;67(4):354–360.

Update: Exertional Hyponatremia, Active Component, U.S. Armed Forces, 1999–2014

From 1999 through 2014, there were 1,506 incident diagnoses of exertional hyponatremia among active component members of the U.S. Armed Forces. Annual incidence rates rose sharply from 2008 through 2010 then decreased by more than 50% from 2010 through 2013. In 2014, the number of cases (n=98) increased by approximately 30% from the previous year. The recent increase in rates overall reflects increased rates in all Services except the Navy. Relative to their respective counterparts, crude incidence rates of exertional hyponatremia for the entire 16-year surveillance period were higher among females, those in the youngest age group, Marines, and recruit trainees. Service members (particularly recruit trainees) and their supervisors must be vigilant for early signs of heat-related illnesses and must be knowledgeable of the dangers of excessive water consumption and the prescribed limits for water intake during prolonged physical activity (e.g., field training exercises, personal fitness training, recreational activities) in hot, humid weather.

Exertional, or exercise-induced, hyponatremia is defined as a low concentration of sodium in the blood (i.e., serum sodium concentration <135 mEq/L) occurring during or up to 24 hours after prolonged physical activity.[1] This condition can have serious and sometimes fatal clinical effects.[1,2] Several risk factors have been associated with the development of exertional hyponatremia; among these are excessive water consumption, excessive sodium losses in sweat, and inadequate sodium intake during prolonged physical exertion, particularly during heat stress.[2–5]

Acute hyponatremia creates an osmotic imbalance between fluids outside and inside of cells. The osmotic gradient causes water to flow from outside to inside the cells of various organs, including the lungs ("pulmonary edema") and brain ("cerebral edema"). Swelling of the brain increases intracranial pressure, which can decrease cerebral blood flow and disrupt brain function (e.g., hypotonic encephalopathy, seizures, coma). Without rapid and definitive treatment to relieve increasing intracranial pressure, the brain stem can herniate through the base of the skull, and life-sustaining functions that are controlled by the cardiorespiratory centers of the brain stem can be compromised.[2–4]

In summer 1997, Army training centers reported five hospitalizations of soldiers for hyponatremia secondary to excessive water consumption during military training in hot weather—one case was fatal and several others required intensive medical care.[6] In April 1998, the U.S. Army Research Institute of Environmental Medicine, Natick, MA, revised the guidelines for fluid replacement during military training in heat. The new guidelines were designed to protect service members from not only heat injury but also hyponatremia due to excessive water consumption. The guidelines limited fluid intake regardless of heat category or work level to no more than 1½ quarts hourly and 12 quarts daily.[7] There were fewer hospitalizations of soldiers for hyponatremia due to excessive water consumption during the year after compared to before implementation of the new guidelines.[7]

This report uses a surveillance case definition for "exertional hyponatremia" to estimate frequencies, rates, trends, geographic locations, and demographic and military characteristics of exertional hyponatremia cases among U.S. military members from 1999 through 2014.

METHODS

The surveillance period was 1 January 1999 through 31 December 2014. The surveillance population included all individuals who served in an active component of the U.S. Armed Forces at any time during the surveillance period. Diagnoses were ascertained from administrative records of medical encounters archived in the Defense Medical Surveillance System (DMSS) which contains electronic records of all actively serving U.S. military members' hospitalizations and ambulatory visits in U.S. military and civilian (contracted/purchased care through the Military Health System) medical facilities worldwide as well as records of medical encounters of service members deployed to southwest Asia/Middle East (as documented in the Theater Medical Data Store [TMDS]).

For surveillance purposes, a case of exertional hyponatremia was defined as a hospitalization or ambulatory visit with a primary (first-listed) diagnosis of "hyposmolality and/or hyponatremia" (ICD-9: 276.1) and no other illness or injury-specific diagnoses (ICD-9: 001–999) in any diagnostic position; or both a diagnosis of "hyposmolality and/or hyponatremia" (ICD-9: 276.1) and at least one of the following within the first three diagnostic positions (dx1–dx3): "fluid overload" (ICD-9: 276.6), "alteration of consciousness" (ICD-9: 780.0x), "convulsions" (ICD-9: 780.39), "altered mental status" (ICD-9: 780.97), "effects of heat/light" (ICD-9: 992.0–992.9), or "rhabdomyolysis" (ICD-9: 728.88).

Medical encounters were not considered case defining events if they included complicating diagnoses such as alcohol/illicit drug abuse; psychosis, depression, or other major mental disorders; endocrine (e.g., pituitary, adrenal) disorders; kidney diseases; intestinal infectious diseases; cancers; major traumatic injuries; or complications of medical care in any diagnostic position. Each individual could be included as a case only once per calendar year.

For surveillance purposes, a "recruit trainee" was defined as an active component member in an enlisted grade (E1–E4) who was assigned to one of the Services' recruit training locations (per the individual's initial military personnel record). For this report, each service member was considered a recruit trainee for the period of time corresponding to the usual length of recruit training in his/her service. Recruit trainees were considered a separate category of enlisted service members in summaries of exertional hyponatremia by military grade overall.

Records of medical evacuations from the U.S. Central Command (CENTCOM) area of responsibility (AOR) (e.g., Iraq, Afghanistan) to a medical treatment facility outside the CENTCOM AOR were analyzed separately. Evacuations were considered case-defining if the affected service members met the above criteria in a permanent military medical facility in the U.S. or Europe from 5 days before to 10 days after their evacuation dates.

RESULTS

From 1999 through 2014, permanent medical facilities reported 1,506 incident diagnoses of exertional hyponatremia among active component members (incidence rate: 6.6 per 100,000 person-years [p-yrs]) **(Table 1)**. In 2014, there were 98 incident diagnoses of exertional hyponatremia (incidence rate: 7.1 per 100,000 p-yrs) among active component members. Incidence rates of exertional hyponatremia peaked in 2010 (12.6 per 100,000 p-yrs) and then declined by more than 50% to 5.3 cases per 100,000 p-yrs in 2013, before increasing slightly in 2014 **(Figure 1)**.

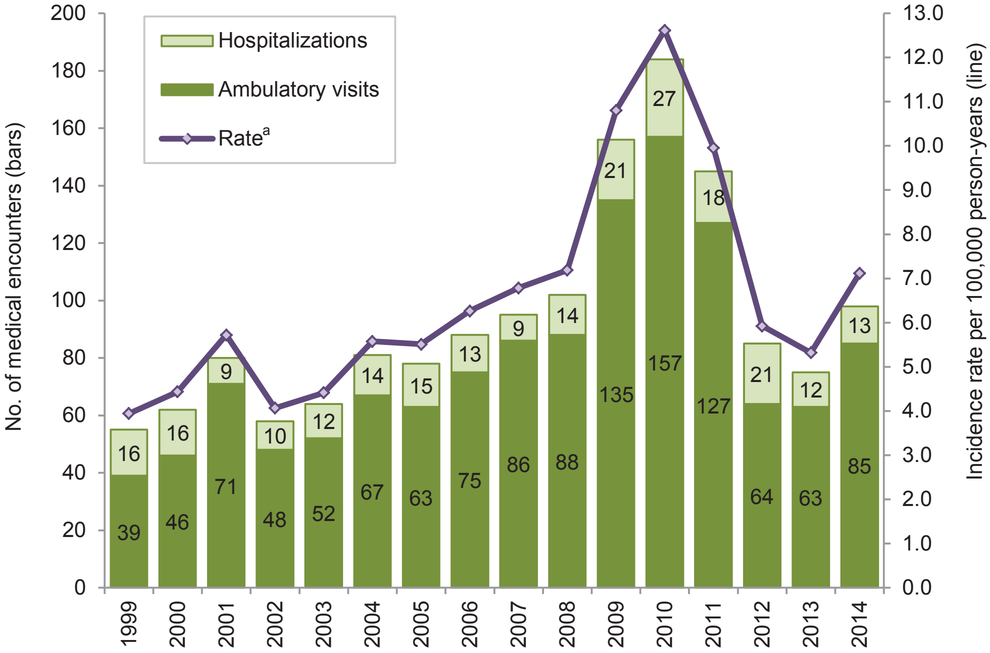
In 2014, among the Services, the highest overall incidence rate was in the Marine Corps (14.8 per 100,000 p-yrs), although the Army had the most cases during the year (n=35) **(Table 1)**. During the 16-year

TABLE 1. Incident cases and incidence rates of exertional hyponatremia, active component, U.S. Armed Forces, 1999–2014

	2014		Total 1999–2014	
	No.	Rate[a]	No.	Rate[a]
Total	98	7.1	1,506	6.6
Sex				
Male	80	6.8	1,248	6.4
Female	18	8.7	258	7.8
Age group				
<20	9	10.3	214	13.1
20–24	26	6.0	457	6.2
25–29	16	4.8	276	5.5
30–34	22	9.8	165	4.8
35–39	12	7.7	174	6.1
40+	13	8.9	220	9.2
Race/ethnicity				
White, non-Hispanic	62	7.4	1,030	7.2
Black, non-Hispanic	16	7.2	184	4.7
Hispanic	7	4.3	144	6.1
Asian/Pacific Islander	5	8.7	60	6.7
Other/unknown	8	8.2	88	6.3
Service				
Army	35	6.9	531	6.5
Navy	14	4.4	218	4.0
Air Force	18	5.6	311	5.7
Marine Corps	28	14.8	420	14.2
Coast Guard	3	7.6	26	4.1
Military status				
Recruit	7	28.4	132	28.4
Enlisted	64	5.8	1,097	5.9
Officer	27	11.0	277	7.4
Military occupation				
Combat-specific	20	10.9	226	7.9
Armor/motor transport	2	3.8	53	5.4
Pilot/air crew	4	7.8	45	5.3
Repair/engineering	16	3.9	277	4.1
Communications/intelligence	22	7.3	257	5.0
Health care	2	1.6	116	6.2
Other	32	12.3	532	12.1
Home of record[b]				
Midwest	22	9.0	243	6.6
Northeast	14	7.9	197	7.2
South	43	7.6	589	6.9
West	15	4.8	244	5.5
Other/unknown	4	5.0	233	6.9

[a]Rate per 100,000 person-years
[b]Home of record self-reported at entry into service

FIGURE 1. Incident cases and incidence rates of exertional hyponatremia, active component, U.S. Armed Forces, 1999–2014



[a]Rate includes inpatient and outpatient encounters

surveillance period, the overall crude incidence rate was also highest in the Marine Corps (14.2 per 100,000 p-yrs), intermediate in the Army and Air Force (6.5 and 5.7 per 100,000 p-yrs, respectively), and lowest in the Navy and Coast Guard (4.0 and 4.1 per 100,000 p-yrs, respectively) **(Table 1, Figure 2)**. In each Service, except the Navy, incidence rates increased during 2013–2014 **(Figure 2)**.

In 2014, 82% of exertional hyponatremia cases (n=80) affected males, but the rate during the year was higher among females (8.7 per 100,000 p-yrs) than males (6.8 per 100,000 p-yrs) **(Table 1)**. Females also had higher overall incidence rates over the entire surveillance period.

In 2014 and during the surveillance period overall, the highest age group-specific incidence rates affected the youngest (<20 years) service members **(Table 1)**. Also, overall rates were higher among white, non-Hispanic than other race/ethnicity groups of service members. Rates among recruit trainees were more than double in 2014 and nearly quadruple overall the rates among other enlisted members and officers.

Exertional hyponatremia by location

During the 16-year surveillance period, exertional hyponatremia cases were diagnosed at U.S. military medical facilities at more than 200 locations; however, six locations were affected by 40 or more cases each and accounted for nearly one-third of all cases **(Table 2)**. The location with the most cases overall was the Marine Corps Recruit Depot (MCRD) Parris Island/Beaufort, SC (n=199). The number of cases at MCRD Parris Island/Beaufort increased in 2014 (n=13) compared to 2013 (n=10) **(data not shown)**.

Exertional hyponatremia in Iraq and Afghanistan

From 2008 through 2014, a total of 77 cases of exertional hyponatremia were diagnosed and treated in Iraq and Afghanistan. Deployed service members who were affected by exertional hyponatremia were most frequently male (n=52; 67.5%), white, non-Hispanic (n=53; 68.8%), aged 20–24 years (n=27; 35.1%), in the Army (n=42; 54.5%), enlisted (n=63; 81.8%), and in communications/intelligence (n=18; 23.4%) and repair/engineering (n=18; 23.4%) occupations **(data not shown)**. During the entire period, six service members were medically evacuated from Iraq or Afghanistan for exertional hyponatremia **(data not shown)**.

EDITORIAL COMMENT

This report documents that, after a 3-year period of declining numbers and rates of exertional hyponatremia diagnoses among active component U.S. military members, numbers and rates of diagnoses increased slightly in 2014.

The results of this report should be interpreted with consideration of several

FIGURE 2. Incidence rates of exertional hyponatremia by service, active component, U.S. Armed Forces, 1999–2014

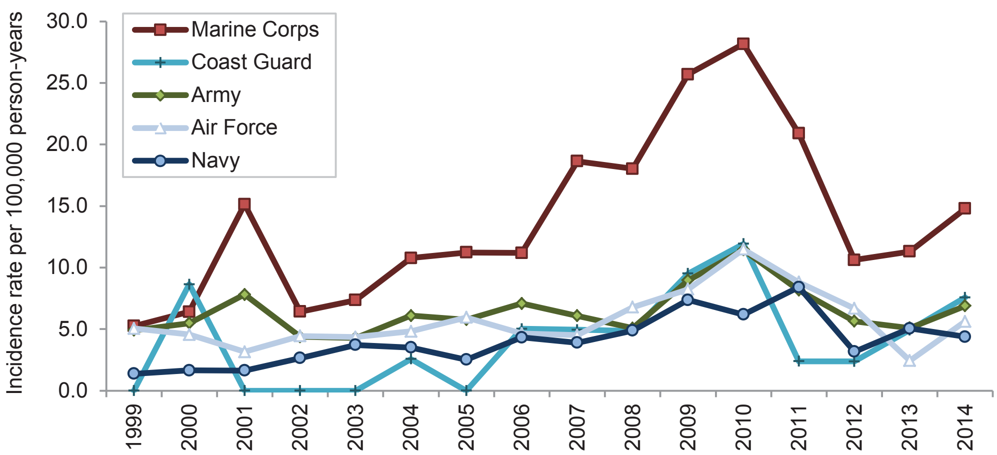


TABLE 2. Incident cases of exertional hyponatremia by installation (with at least 25 cases during the period), active component, U.S. Armed Forces, 1999–2014

Location of diagnosis	No.	%
MCRD Parris Island/ Beaufort, SC	199	13.2
Fort Benning, GA	93	6.2
MCB Camp Lejeune/ Cherry Point, NC	49	3.3
Lackland AFB, TX	48	3.2
Fort Bragg, NC	48	3.2
Walter Reed NMMC, MD[a]	46	3.1
MCB Camp Pendleton, CA	39	2.6
NMC San Diego, CA	39	2.6
NMC Portsmouth, VA	37	2.5
Fort Jackson, SC	32	2.1
MCB Quantico, VA	31	2.1
Fort Leonard Wood, MO	25	1.7
Other locations	820	54.4
Total	1,506	100.0

[a]Walter Reed National Military Medical Center (NMMC) is a consolidation of National Naval Medical Center (Bethesda, MD) and Walter Reed Army Medical Center (Washington, DC). This number represents the sum of the two sites prior to the consolidation (November 2011) and the number reported at the consolidated location.

MCRD=Marine Corps Recruit Depot; MCB=Marine Corps Base; NMC=Naval Medical Center

limitations. For example, there is not a diagnostic code specific for "exertional hyponatremia." Thus, for surveillance purposes, cases of presumed exertional hyponatremia were ascertained from records of medical encounters that included diagnoses of "hyposmolality and/or hyponatremia," but not of other conditions (e.g., metabolic, renal, psychiatric, or iatrogenic disorders) that increase the risk of hyponatremia in the absence of physical exertion or heat stress. As such, the results of this analysis should be considered estimates of the actual incidence of symptomatic exertional hyponatremia from excessive water consumption among U.S. military members. The accuracy of estimated numbers, rates, trends, and correlates of risk depends on the completeness and accuracy of diagnoses that are reported on standardized records of relevant medical encounters. As a result, an increase in reporting of diagnoses indicative of exertional hyponatremia may reflect, at least in part, increasing awareness of, concern regarding, and aggressive management of incipient cases by military supervisors and primary healthcare providers.

In the past, concerns regarding hyponatremia from excessive water consumption were focused at training—particularly recruit training—installations. In this analysis, rates were relatively high among the youngest—hence, the most junior—service members, and the most cases were diagnosed at medical facilities that support large recruit training centers and large Army and Marine Corps combat units (e.g., MCRD Parris Island/Beaufort, SC; Fort Benning, GA; Camp Lejeune/Cherry Point, NC; Fort Bragg, NC). In many circumstances (e.g., recruit training, Ranger School), military trainees rigorously adhere to standardized training schedules—regardless of weather conditions. In hot, humid weather, commanders, supervisors, instructors, and medical support staff must be aware of and enforce guidelines for work-rest cycles and water consumption.

Although there have been no deaths from hyponatremia among active duty service members since the late 1990s, other military populations have reported deaths due to exertional hyponatremia. For example, recently a well-conditioned and heat-adapted 20-year-old soldier in the South African National Defence Force died of exertional hyponatremia during a timed training march.[8] Service members and their supervisors must be knowledgeable of the dangers of excessive water consumption and the prescribed limits for water intake during prolonged physical activity (e.g., field training exercises, personal fitness training, recreational activities) in hot, humid weather. The current U.S. Military Fluid Replacement Guidelines can be found at: http://hprc-online.org/nutrition/files/current-u-s-military-fluid-replacement.

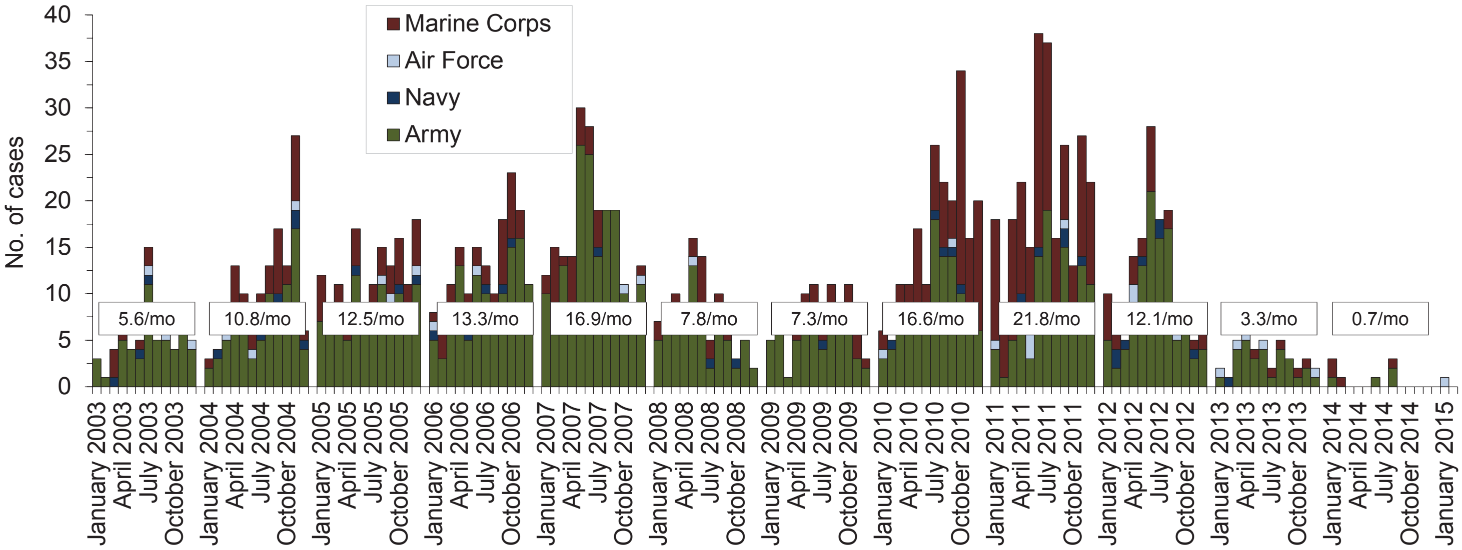
Women had relatively high rates over the entire surveillance period; women may be at greater risk because of lower fluid requirements and longer periods of exposure to risk during some training exercises (e.g., land navigation courses, load-bearing marches).[5] Service members (particularly recruit trainees and women) and their supervisors must be vigilant for early signs of heat-related illnesses—and immediately and appropriately (but not excessively) intervene in such cases.

REFERENCES

1. Hew-Butler T, Ayus JC, Kipps C, et al. Statement of the Second International Exercise-Associated Hyponatremia Consensus Development Conference, New Zealand, 2007. *Clin J Sport Med*. 2008;18:111.
2. Montain SJ. Strategies to prevent hyponatremia during prolonged exercise. *Curr Sports Med. Rep.* 2008;7:S28–S35.
3. Chorley J, Cianca J, Divine J. Risk factors for exercise-associated hyponatremia in non-elite marathon runners. *Clin J Sport Med*. 2007 Nov;17(6):471–477.
4. O'Connor RE. Exercise-induced hyponatremia: causes, risks, prevention, and management. *Cleve Clin J Med*. 2006;73(3):S13–S18.
5. Carter III, R. Exertional heat illness and hyponatremia: an epidemiological prospective. *Curr Sports Med Rep*. 2008;7(4):S20–S27.
6. Army Medical Surveillance Activity. Case reports: hyponatremia associated with heat stress and excessive water consumption: Fort Benning, GA; Fort Leonard Wood, MO; Fort Jackson, SC, June–August 1997. *MSMR*. Sep 1997;3(6):2–3,8.
7. Army Medical Surveillance Activity. Surveillance trends: hyponatremia associated with heat stress and excessive water consumption: the impact of education and a new Army fluid replacement policy. *MSMR*. Mar 1999;3(6):2–3,8–9.
8. Nolte HW, Hew-Butler T, Noakes TD, Duvenage CS. Exercise-associated hyponatremic encephalopathy and exertional heatstroke in a soldier: high rates of fluid intake during exercise caused rather than prevented a fatal outcome. *Phys Sportsmed*. 2015 Feb;43(1):93–98.

Deployment-related Conditions of Special Surveillance Interest, U.S. Armed Forces, by Month and Service, January 2003–February 2015 (data as of 26 March 2015)

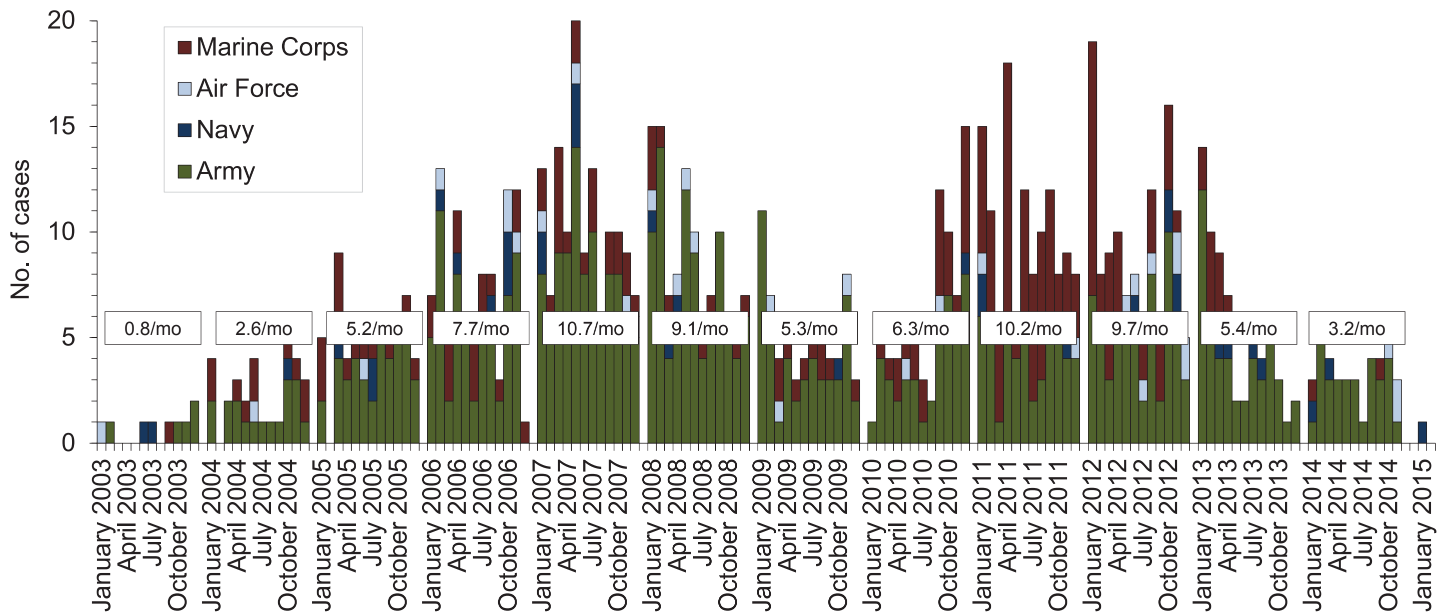
Amputations (ICD-9-CM: 887, 896, 897, V49.6 except V49.61–V49.62, V49.7 except V49.71–V49.72, PR 84.0–PR 84.1, except PR 84.01–PR 84.02 and PR 84.11)[a]



Reference: Army Medical Surveillance Activity. Deployment-related condition of special surveillance interest: amputations. Amputations of lower and upper extremities, U.S. Armed Forces, 1990–2004. *MSMR*. 2005;11(1):2–6.

[a]Indicator diagnosis (one per individual) during a hospitalization while deployed to/within 365 days of returning from deployment.

Heterotopic ossification (ICD-9: 728.12, 728.13, 728.19)[b]

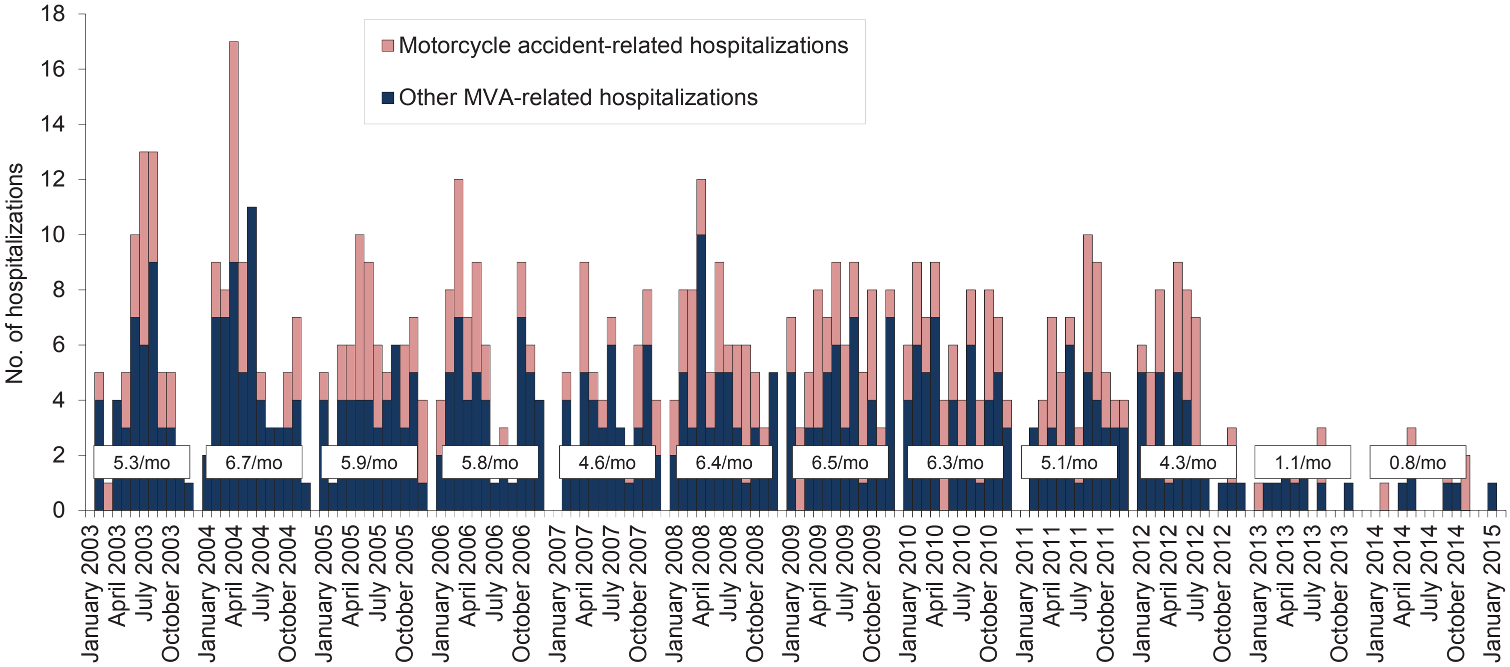


Reference: Army Medical Surveillance Activity. Heterotopic ossification, active components, U.S. Armed Forces, 2002–2007. *MSMR*. 2007;14(5):7–9.

[b]One diagnosis during a hospitalization or two or more ambulatory visits at least 7 days apart (one case per individual) while deployed to/within 365 days of returning from deployment.

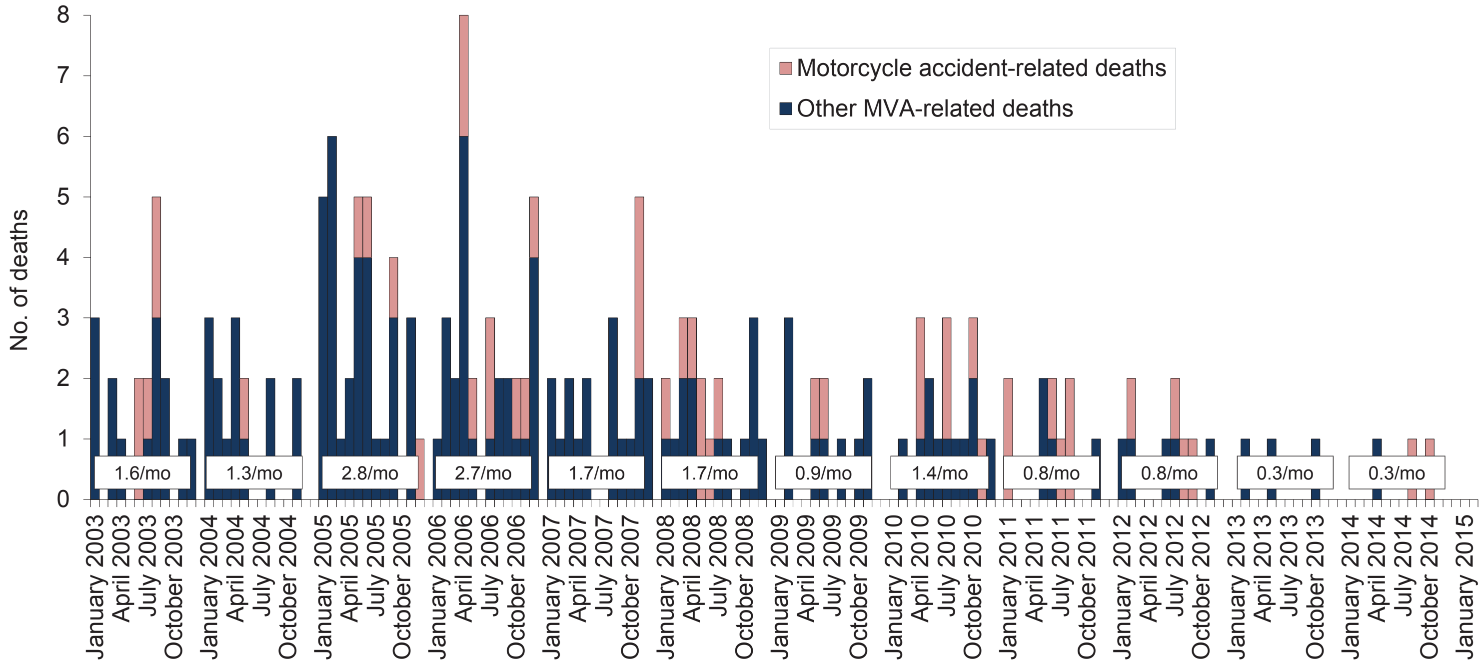
Deployment-related Conditions of Special Surveillance Interest, U.S. Armed Forces, by Month and Service, January 2003–February 2015 (data as of 18 March 2015)

Hospitalizations outside of the operational theater for motor vehicle accidents occurring in non-military vehicles (ICD-9-CM: E810–E825; NATO Standard Agreement 2050 (STANAG): 100–106, 107–109, 120–126, 127–129)



Note: Hospitalization (one per individual) while deployed to/within 90 days of returning from OEF/OIF/OND. Excludes accidents involving military-owned/special use motor vehicles. Excludes individuals medically evacuated from CENTCOM and/or hospitalized in Landstuhl, Germany, within 10 days of another motor vehicle accident-related hospitalization.

Deaths following motor vehicle accidents occurring in non-military vehicles and outside of the operational theater (per the DoD Medical Mortality Registry)



Reference: Armed Forces Health Surveillance Center. Motor vehicle-related deaths, U.S. Armed Forces, 2010. *MSMR*. Mar 2011;17(3):2–6.

Note: Death while deployed to/within 90 days of returning from OEF/OIF/OND. Excludes accidents involving military-owned/special use motor vehicles. Excludes individuals medically evacuated from CENTCOM and/or hospitalized in Landstuhl, Germany, within 10 days prior to death.

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