APRIL 2019

Volume 26
Number 4

MSMR

MEDICAL SURVEILLANCE MONTHLY REPORT

A publication of the Armed Forces Health Surveillance Branch

Modeling Lyme Disease Host Animal Habitat Suitability, West Point, New York

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As the most frequently reported vector-borne disease among active component U.S. service members, with an incidence rate of 16 cases per 100,000 person-years in 2011, Lyme disease poses both a challenge to healthcare providers in the Military Health System and a threat to military readiness. Spread through the bite of an infected blacklegged tick, infection with the bacterial cause of Lyme disease can have lasting effects that may lead to medical discharge from the military. The U.S. Military Academy at West Point is situated in a highly endemic area in New York State. To identify probable areas where West Point cadets as well as active duty service members stationed at West Point and their families might contract Lyme disease, this study used Geographic Information System mapping methods and remote sensing data to replicate an established spatial model to identify the likely habitat of a key host animal—the white-tailed deer.

WHAT ARE THE NEW FINDINGS?

This study used an established spatial analysis method to determine likely high-risk areas for contracting Lyme disease from ticks (*Ixodes scapularis*) near West Point, NY. Urban population centers in this area have lower habitat suitability values for white-tailed deer, the tick's host, while rural areas and military training grounds have higher suitability values.

WHAT IS THE IMPACT ON READINESS AND FORCE HEALTH PROTECTION?

Lyme disease, if not diagnosed early, can result in post-treatment Lyme disease syndrome (PTLDS). The symptoms resulting from Lyme disease and possible PTLDS may render service members non-deployable and may result in medical separations from service. Military bases in endemic areas need to increase awareness of the local Lyme disease threat and facilitate the implementation of superior tick bite prevention measures.

Lyme disease (LD) is the most frequently reported vector-borne disease in the U.S., with over 36,429 confirmed and probable cases in 2016.[1] The vast majority of LD cases are reported from 14 states in the Northeast and Upper Midwest.[2] New York State alone accounted for 11.4% and 10.0% of confirmed cases nationally in 2015 and 2016, respectively.[3] Moreover, Southeastern NY—an area that includes the U.S. Military Academy (USMA) at West Point that is home to over 4,400 cadets and 4,200 active duty service members (ADSMs) and their families—has the highest burden of LD **(Figure 1)**. One study reported that ticks in Southeastern NY had infection rates as high as 55% for the bacterial cause of LD.[4]

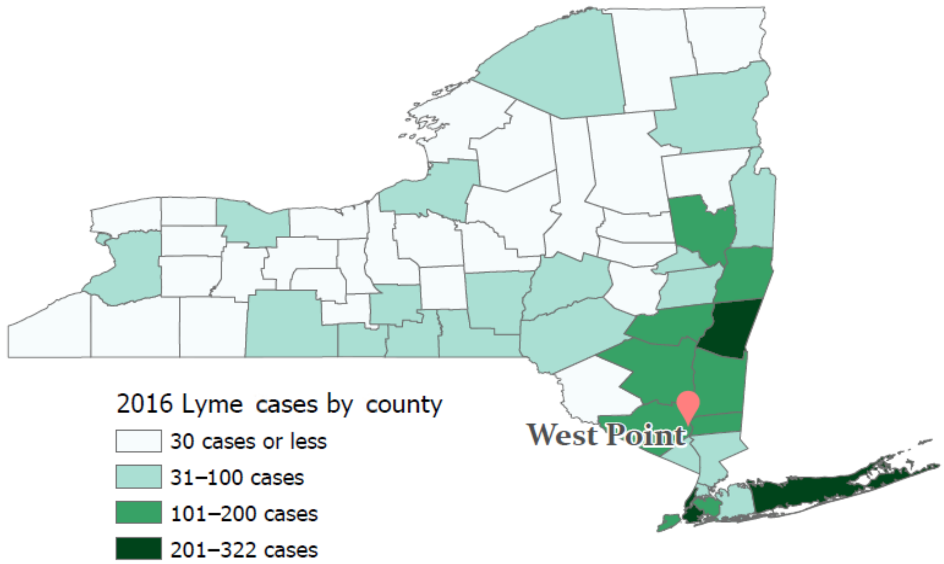
In the past few years, LD has resulted in the removal of at least 2 cadets from the USMA because of medical ineligibility for commissioning. In addition, 2 recently commissioned Second Lieutenants have been discharged from the Army because of medical issues as a result of chronic LD. Further research on the prevalence of LD at West Point as well as the diagnostic accuracy of techniques employed there is ongoing. Results of these studies may increase the need for identification of high-risk areas within the reservation and the surrounding area.

Cases of LD in humans are a result of several factors (e.g., vectors and reservoir hosts) that facilitate the transmission of the causative bacterium (*Borrelia burgdorferi*) to humans. The most common vector of *B. burgdorferi* in the Northeastern U.S. is *Ixodes scapularis*, commonly known as the blacklegged tick or deer tick.[5] While *Ixodes* spp larvae and nymphs prefer small mammalian hosts, including the white-footed mouse (a competent reservoir for *B. burgdorferi*),[6,7] adult ticks prefer white-tailed deer (a less competent host of this bacterium).[8,9]

There are few methods to determine tick density in a given area. One common method, tick dragging, was used at West Point in 2016 and showed that *B. burgdorferi*-infected ticks were found in both military family housing neighborhoods and cadet training areas. (The housing area for cadets was not tested since it consisted of impervious surfaces and thus was not a likely tick habitat).[10] While tick dragging can locate *B. burgdorferi*-infected ticks, this technique is limited by its time intensive nature, the difficulty in finding and extracting the small tick larvae and nymphs from the drag cloth, and its susceptibility to weather and temperature conditions.[11] These limitations of tick dragging demonstrate the need for improved tick habitat prediction.

To address these limitations, some studies have used spatial analysis and predictive modeling for LD vectors and have focused on a variety of variables including soil type, vegetation, small mammal abundance, temperature, humidity, geology, and predator abundance.[8,12–16] However, these studies have produced conflicting results, which may be due to confounding effects of various geographic factors, including inconsistencies such as a positive correlation between tick abundance and precipitation in areas with soils that drain quickly (such as sand) and a negative correlation between tick abundance and precipitation in areas with soils that drain slowly (such as clay).[5] Studies of tick tree preferences also have demonstrated inconsistent findings.[12,17] Thus, it is difficult to pinpoint the environmental preferences of *I. scapularis* without the implementation of a control habitat and/or standardization of data capture across multiple studies.

FIGURE 1. Lyme disease cases by county, New York State, 2016[a]



[a]Author: Sara Schubert, 30 September 2018 Coordinate System: GCS WGS 1984. Reference: Centers for Disease Control and Prevention. Lyme Disease 2017, https://www.cdc.gov/lyme/stats/index.html.

Some studies also have focused on host animal habitats in order to estimate the spatial distribution of *I. scapularis*. Results of studies regarding the importance of host animals in LD and *I. scapularis* ecology are mixed.[18,19] However, studies agree that deer are an important part of the ecology and contribute to the continued spread of this disease.[17,20] In light of this, Chen et al. used Geographic Information System (GIS) mapping methods combined with spatial analysis techniques to create a habitat suitability model for white-tailed deer in Ontario, Canada.[9] The results of this study demonstrated that high suitability areas for white-tailed deer corresponded with high tick abundance.[9]

At the time of this report, no studies have examined white-tailed deer habitat suitability at West Point. The current study addresses this gap by using open data in a model similar to that employed by Chen et al. to identify the LD risk for West Point cadets, ADSMs, and their families.

METHODS

Study area

The USMA at West Point is located in Orange County, which is situated on the Hudson River in upstate NY. This area is semi-rural, heavily wooded, and relatively mountainous, with the highest peak rising 1,664 feet above the Hudson River.[21]

Data sources

To determine the most likely geographic distribution of blacklegged ticks and the resulting areas of potentially high LD prevalence, Chen and colleagues' model for deer habitat suitability was replicated using open data for Orange County. The model sought to determine where deer have the best access to shelter (i.e., land cover and terrain slope), food (i.e., vegetation type), water, diversity of land cover, and proximity to urban areas and roads (i.e., suitability criteria). Data on vegetation and land use patterns were obtained from the U.S. Geological Survey's (USGS's) National Gap Analysis Project (GAP) Land Cover dataset, which represents vegetation and land use patterns for the continental U.S. derived from 1999–2001 Landsat Thematic Mapper satellite imagery.[22] Data on all roads in Orange County were obtained from the Orange County GIS Division.[23] Water body data were obtained from the USGS's National Hydrography Dataset in the form of a vector dataset (i.e., representation using points, lines, and polygons); these data were publically available for the contiguous U.S. at a scale of 1:24,000 or better.[24] Data needed to calculate the slope of the terrain were obtained from USGS's National Elevation Dataset in raster form (i.e., representation as a surface divided into a grid of cells) with a resolution of approximately 10 meters (one-third arc-second).[25]

Data processing and analysis

To transform the 4 datasets outlined above into a single habitat suitability layer, each dataset was reclassified using a scale from 1 (less suitable) to 5 (most suitable) using ArcGIS Pro software, version 2.1.2 (2018, ESRI, Redlands, CA). The 7 suitability criteria used in the analysis are shown in **Table 1**.

To determine the suitability of the vegetation for the shelter and food layers, the original GAP land cover values were reclassified to the coordinating suitability values from Chen and colleagues' model.[9] These values are presented in **Table 2**. The terrain slope also contributed to shelter suitability. Relatively flat areas were classified as most suitable, while steeper slopes were classified as less suitable. Chen and colleagues' analysis used a maximum distance of 1 mile to water for a suitability rating of 5; however, because of the abundance of water in Orange County, a maximum distance of 1 mile from a water body covered over 95% of the county. To better determine suitability, distances of 0.5 miles, 1 mile, and 1.5 miles were used to create the buffers. Similarly, multiple ring buffers were used for roads and urban areas. To determine the diversity of the land cover, the ArcGIS Pro focal statistics tool was used to determine the variety of cells within a circle with a 0.5 mile radius; resulting values were reclassified to the 1 to 5 suitability values, with higher vegetative diversity receiving a value of 5. Once each dataset layer was reclassified to the appropriate suitability values, vector data were converted to raster in order to calculate the suitability layer. These layers were then combined using a weighted sum to create 1 layer with an overall habitat suitability as follows: habitat suitability = land cover (shelter) * 0.148 + terrain slope (shelter) * 0.074 + vegetation (food) * 0.220 + proximity to water

TABLE 1. Chen et al.[9] model adapted for predicting deer habitat suitability in Orange County, NY

Criterion (weight)	Measurement	Data source	GIS data processing	Original value	Suitability value[a]
Shelter/ land cover (4/27)	Type of vegetation	GAP land cover[22]	Reclassify	38–584	See Table 2
Shelter/ terrain slope (2/27)	Degrees	National Elevation Dataset[25]	Reclassify	13.41–20.89	1
				8.44–13.41	2
				5.02–8.44	3
				2.36–5.02	4
				0–2.36	5
Food (2/9)	Type of vegetation	GAP land cover[22]	Reclassify	38–584	See Table 2
Proximity to water (2/9)	Miles	USGS hydrography, water body[24]	Reclassify, multiple ring buffer	1–1.5 miles	3
				0.6–1 miles	4
				0–0.5 miles	5
Diversity of land cover (1/6)	Variety of vegetation	GAP land cover[22]	Reclassify, focal statistics (variety)	7	1
				12	2
				16	3
				19	4
				27	5
Proximity to urban areas (1/12)	Miles	GAP land cover[22]	Reclassify, extract urban areas, buffer	0–0.8	1
				0.8–1.6	2
				1.6–2.4	3
				2.4–3.1	4
				>3.1	5
Proximity to roads (speed limit >30 mph) (1/12)	Miles	Orange County roads[23]	Reclassify, extract major roads, multiple ring buffer	0–0.8	1
				0.8–1.6	2
				1.6–2.4	3
				2.4–3.1	4
				>3.1	5

[a]Scale: 1 (less suitable) to 5 (most suitable)

GIS, Geographic Information System; GAP, Gap Analysis Project; USGS, U.S. Geological Survey; mph, miles per hour

* 0.220 + diversity of land cover (shelter) * 0.167 + proximity to urban areas * 0.083 + proximity to roads * 0.083.

RESULTS

Figure 2 shows the map resulting from the final suitability analysis for white-tailed deer habitats within Orange County. Areas in shades of yellow and green are less suitable for deer and, as a result, are less likely to be areas where humans will contract LD. Conversely, areas in orange and red are more suitable habitats for white-tailed deer and are presumably areas where humans are more likely to encounter the blacklegged tick and contract LD. Areas around the cities of Newburgh, Middletown, and Monroe appear to be primarily green (unsuitable deer habitat). Urban population centers with reduced green space, increased density of roads, and continuous vehicular traffic offer reduced food and shelter for white-tailed deer, resulting in lower suitability values. Because water is prevalent throughout Orange County, its effect on habitat suitability was not pronounced. There were few areas further than 1.5 miles from a water body, which resulted in the entire county having suitability values that ranged between 2 and 4. The large uniform yellow area to the southwest of Goshen stands out from the uneven texture of the rest of the county. This area contains the Wallkill River and large stretches of cropland, which is only moderately suitable for deer given the shelter suitability value of 3. Additionally, Highway 26 runs the length of this section, keeping suitability values relatively low overall.

The pixel size for GAP land cover data is 30 meters, which makes it difficult to look specifically at West Point within Orange County **(Figure 2)**. However, zooming in on this portion of the map reveals that the training areas, where cadets spend the majority of their summers, contain several habitats with medium to high suitability for white-tailed deer. The main garrison, located in the northeast portion of the reservation, is primarily green and yellow (low suitability). This region is where cadets spend the majority of their time during the academic year and also where ADSMs and family members reside.

EDITORIAL COMMENT

As the most frequently reported vector-borne disease in the U.S., with an incidence rate of 16 cases per 100,000 person-years among active component service members in 2011, LD poses both a challenge to healthcare providers in the Military Health System and a threat to military readiness.[26] LD, if not diagnosed early, can result in post-treatment LD syndrome (PTLDS). The symptoms resulting from LD and possible PTLDS may render service members non-deployable and may result in medical separations from service.

Research focused specifically on LD among ADSMs and their families on military reservations has found that family members were affected at a higher rate than service members.[27] Analysis of the U.S. Army's Public Health Command Human Tick Test Kit Program data revealed a similar finding that only 23% of the ticks submitted to the program were removed from ADSMs.[28] Additionally, this study demonstrated that the crude overall incidence of LD increased with both age and rank. The positive correlation between LD incidence and age is also

TABLE 2. Vegetation reclassification table for alignment with Chen et al.'s[9] model

Original value (GAP land cover)	Land cover description	Shelter suitability value[a]	Food suitability value[a]
38	Ruderal forest	5	3
64	Oak/chestnut forest	5	3
78	Hickory forest & woodland	5	3
90	Managed tree plantation	4	3
91	Northern native ruderal forest	4	3
95	Hemlock—hardwood forest	5	4
98	Northern hardwoods forest	5	4
99	Oak forest	5	4
100	White pine forest	5	4
197–199	Silver maple forest	3	3
204	Silver maple forest—green ash	2	3
207	Alkaline swamp systems	2	2
208	Swamp forests	2	2
341	Pitch pine barrens	5	2
553	Barren	2	2
556	Cultivated cropland	3	5
557	Pasture & hay field crop	3	5
558	Annual grassland	3	4
561	Shrub	3	5
562	Wetland vegetation	2	2
563	Upland vegetation—treed	4	4
567	Grass/forb regeneration	3	4
568	Shrub regeneration	3	5
575	Disturbed shrub regeneration	3	4
579	Open water	1	1
581–583	Developed & urban	1	2
584	High-intensity developed & urban	1	1

[a]Scale 1 (less suitable) to 5 (most suitable)
GAP, Gap Analysis Project

seen in the civilian population.[29] However, the association of higher incidence with higher rank seems contrary to the assumption that spending greater amounts of time outdoors escalates the risk for LD and other tick-borne diseases.[20] This discrepancy may be due, at least in part, to an assumption that LD is primarily contracted peridomestically (around human habitations). This assumption is not unique to military-specific studies and is generally difficult to confirm without additional data from patients.[5,20,30] Socio-cultural factors also may explain this discrepancy. ADSMs are provided a uniform treated with permethrin and are ordinarily instructed on vector-control measures, such as tucking pants into boots and conducting tick checks.[7,27,31] These public health prevention measures may assist in decreasing LD cases among ADSMs; however, additional data are needed to determine the effectiveness of these measures.

The finding of low suitability around the main garrison is contradictory to the assumption that LD is primarily contracted near domestic areas; however, as noted in other peridomestic studies, further research examining human behavior in conjunction with ecologic risk is warranted.[20] Higher resolution land cover data for the entire West Point reservation could increase the accuracy of predicting deer habitat and allow for improved identification of areas where the risk of exposure to LD-infected ticks is high.

There are important limitations to consider when interpreting the results of the current study. First, because the cell resolution (30 meters) of the dataset employed in the analysis was so much greater than the minimum mapping unit area (1 acre), some generalization of land cover was required, which may have created bias within the analysis where vegetation patches were too small to be properly coded. However, this bias is most likely non-differential since both suitable and non-suitable deer habitats were equally likely to be missed during the aggregation. Second, the current study did not incorporate information on deer density or density of *B. burgdorferi*-positive *I. scapularis* on the military reservation. Identifying an association between the deer habitat suitability values and deer and/or tick density would have suggested that the habitat and environmental conditions of the white-tailed deer may also impact the abundance of the tick.

While the current spatial analysis did not provide a high-resolution mapping of habitat suitability for deer within the West Point reservation, the lower resolution map did provide some insight into variations in habitat suitability for deer (the *I. scapularis* host) within and around the reservation, an area of high LD prevalence. Further analysis of where LD cases acquire their tick bites could enhance the spatial analysis method used here. Moreover, the analysis method could be used to generate maps of deer habitat suitability in other counties or parts of the country. All of the data for this study were publicly accessible, with the majority available on a national level, making this type of suitability map easy to generate for various areas within the U.S. These maps may then be used to increase awareness of LD, the factors leading to this disease, and the proper prevention techniques, including vector control and preventive measures. When combined with higher spatial resolution data, this mapping method could provide the more detailed spatial analysis necessary for better implementation of vector control programs and targeted promotion of LD awareness and prevention.

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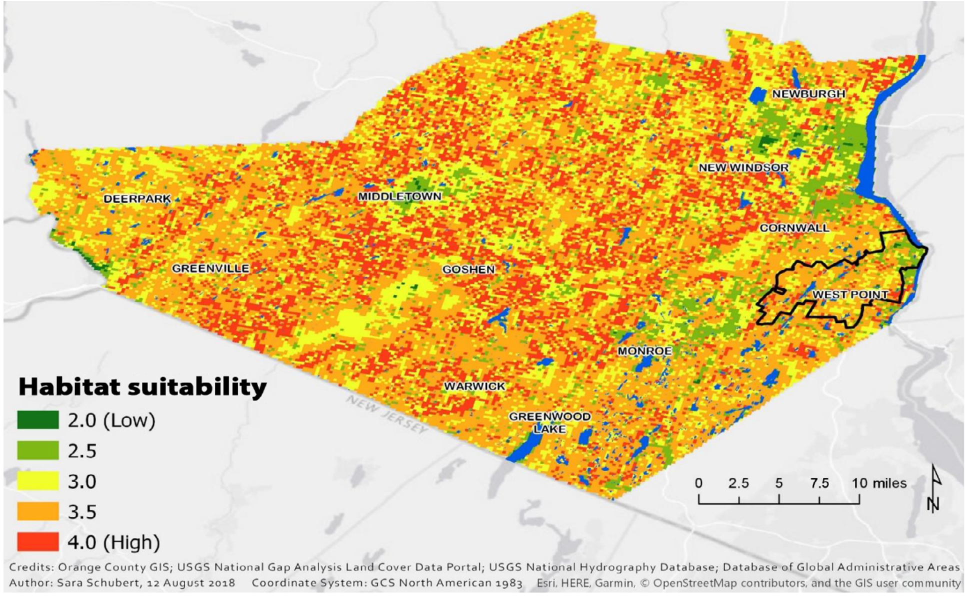
FIGURE 2. White-tailed deer habitat suitability map, Orange County, NY



Ackowledgment: The authors thank Jennifer Moore Bernstein (PhD), Lecturer, Spatial Sciences Institute, University of Southern California Dornsife College of Letters, Arts and Sciences for her review of the initial spatial analysis. They also thank LTC Jason Barnhill, Academy Professor in the Chemistry and Life Science Department of U.S. Military Academy, West Point, for introducing and inspiring them to pursue tick-related research.

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Incidence, Timing, and Seasonal Patterns of Heat Illnesses During U.S. Army Basic Combat Training, 2014–2018

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Risk factors for heat illnesses (HIs) among new soldiers include exercise intensity, environmental conditions at the time of exercise, a high body mass index, and conducting initial entry training during hot and humid weather when recruits are not yet acclimated to physical exertion in heat. This study used data from the Defense Health Agency's–Weather-Related Injury Repository to calculate rates and to describe the incidence, timing, and geographic distribution of HIs among soldiers during U.S. Army basic combat training (BCT). From 2014 through 2018, HI events occurred in 1,210 trainees during BCT, resulting in an overall rate of 3.6 per 10,000 BCT person-weeks (p-wks) (95% CI: 3.4–3.8). HI rates (cases per 10,000 BCT p-wks) varied among the 4 Army BCT sites: Fort Benning, GA (6.8); Fort Jackson, SC (4.4); Fort Sill, OK (1.8); and Fort Leonard Wood, MO (1.7). Although the highest rates of HIs occurred at Fort Benning, recruits in all geographic areas were at risk. The highest rates of HI occurred during the peak training months of June through September, and over half of all HI cases affected soldiers during the first 3 weeks of BCT. Prevention of HI among BCT soldiers requires relevant training of both recruits and cadre as well as the implementation of effective preventive measures.

WHAT ARE THE NEW FINDINGS?

During 2014–2018 BCT classes, the greatest number of HIs occurred in week 2. The highest overall rate of HI was at Fort Benning (6.8 cases per 10,000 p-wks), followed by Fort Jackson (4.5 per 10,000 p-wks), Fort Sill (1.8 per 10,000 p-wks), and Fort Leonard Wood (1.7 per 10,000 p-wks).

WHAT IS THE IMPACT ON READINESS AND FORCE HEALTH PROTECTION?

Service members experience the highest rates of HIs during the first phase of BCT. Entry month should be considered as a modifiable factor to reduce HI rates during training. The findings of this analysis may inform Commanders at each training location about the time of year that targeted mitigation strategies could be most effective.

U.S. military training activities in hot and humid environments pose competing demands from a public health perspective because of the military's obligation to perform realistic training to develop operational capability and readiness while also needing to protect service members against heat-related illness. For example, a recent study examining the risk and timing of heat illness (HI) in the U.S. active duty (AD) Army population demonstrated that the peak incidence of HI occurs during the first 2 months of duty.[1] This period is when soldiers are engaged in initial entry training (IET). IET encompasses a variety of courses, each with unique exposures that may affect the risk of HI.

IET consists of 2 phases: basic combat training (BCT) and advanced individual training (AIT). BCT, which lasts 10 weeks, is followed by AIT, which varies from 5 to over 20 weeks, depending on military occupational specialty.[2] In one station unit training (OSUT), BCT and AIT take place at the same installation. The 10-week BCT course is conducted at 4 locations: Fort Benning, GA; Fort Jackson, SC; Fort Leonard Wood, MO; and Fort Sill, OK. **Figure 1** provides a summary timeline view of the IET process. This study only includes the 10-week period of BCT (i.e., recruits participating in BCT as a part of OSUT were excluded).

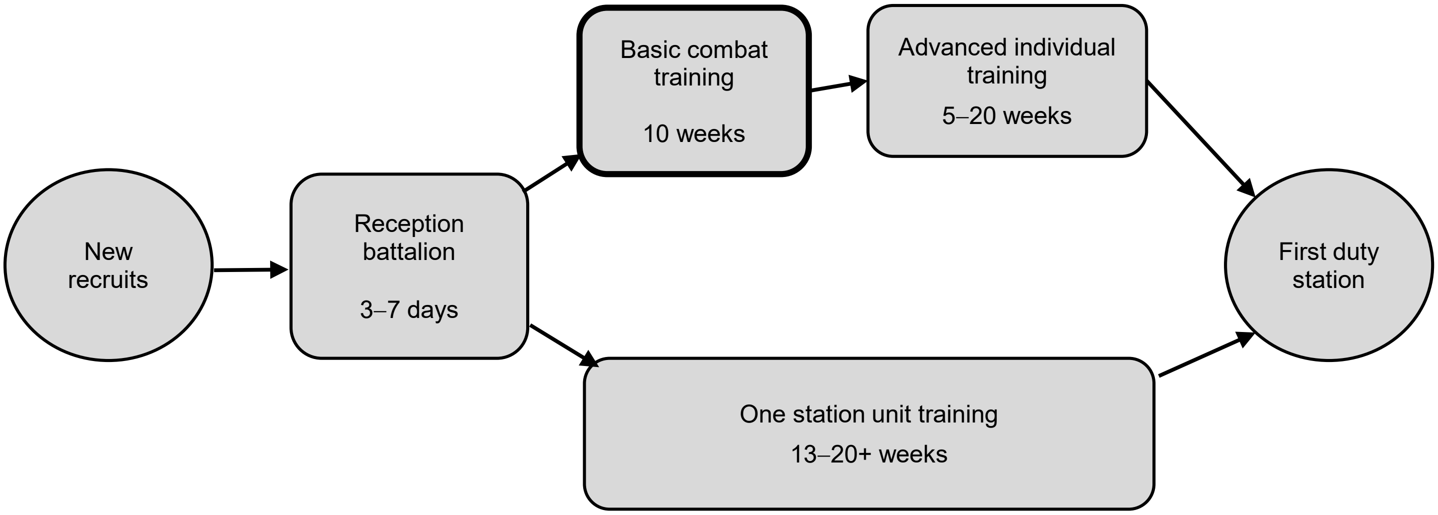
No recently published studies have reported HI rates during BCT. The current study assessed the incidence, timing, and geographic distribution of HI during BCT. Information about the timing and geographic location of HI in this population could inform efforts to reduce the burden of HI during the conduct of training essential to the development of individual skills needed for operational capability and readiness of the U.S. Army.

METHODS

Study design

The current study employed a retrospective cohort design using data from the Defense Health Agency's (DHA)–Weather-Related Injury Repository (WRIR). The WRIR utilizes many available data sources with the goal of being the most complete record system possible for weather-related injuries in Army soldiers. The WRIR enables researchers to review prior years' data and provides contextual perspective to emerging trends. The WRIR includes

FIGURE 1. Global view of the U.S. Army initial entry training process



6 main data sources: hospital admissions (from the Standard Inpatient Data Record [SIDR] and from TRICARE Encounter Data–Institutional [TED-I]), in-theater medical records (from the Theater Medical Data Store [TMDS]), reportable medical events (RMEs), and outpatient encounters (from the Comprehensive Ambulatory/Professional Encounter Record [CAPER] and from TRICARE Encounter Data–Non-Institutional [TED-NI]). The WRIR began collecting data in 2014, so it includes International Classification of Diseases (ICD) codes from both the 9th and 10th revisions.

Study population

All U.S. Army enlisted soldiers who began BCT for the first time at any of the 4 BCT sites from January 2014 through December 2018 were included in the analysis. In order to better compare variables of interest in the training population, recruits conducting BCT as part of OSUT were excluded from the analysis. BCT rosters from 2014–2018 were downloaded from the Army Training Requirements and Resources System (ATRRS). Each BCT site has a unique school code, which was used to pull the data from ATRRS.

Outcome

The outcome of interest was the occurrence of any HI. For this analysis, the identification of a case of HI was based on the Armed Forces Health Surveillance Branch (AFHSB) surveillance case definition and included heat exhaustion (HE) and heat stroke (HS).[3] The AFHSB case definition defines a case of HI as 1 hospitalization or outpatient medical encounter with selected diagnoses of HI **(Table 1)** in the primary or secondary diagnostic position or 1 record of an RME of HI reported to the Disease Reporting System internet.[4]

The incidence date was the date of the first hospitalization, outpatient encounter, or RME associated with an HI. For individuals with more than 1 type of HI medical encounter during BCT, HS is prioritized over HE. Outcome data extracted from the WRIR were matched to ATRRS BCT roster data by social security number. Cases were included in the analysis only if the first encounter date fell between a recruit's first and last day of class in BCT.

Basic combat training exposure time and seasonality

Army BCT is conducted throughout the year and includes the following 3 phases:

Red phase (phase 1; weeks 1–3): The red phase consists of an environment where recruits must demonstrate that they possess the foundation for physical fitness, resiliency, and a level of adaptability to military life. Strenuous outdoor activities with an overlapping risk of heat exposure include 2.5- and 5-mile foot marches.

White phase (phase 2; weeks 4–6): The white phase is centered on the development of basic combat skills, with special emphasis on weapons qualification and physical readiness training. Strenuous outdoor activities with an overlapping risk of heat exposure include a 7.5-mile foot march, land navigation exercises, and time spent at rifle ranges.

Blue phase (phase 3; weeks 7–10): The blue phase includes a 10-mile foot march and concentrates on tactical training, increased soldier responsibilities, and demonstration of teamwork and self-discipline. Recruits are evaluated in basic soldiering skills and prepared for AIT. The blue phase culminates in a field training exercise and the demonstration of proficiency in warrior tasks and battle drills.

Recruit exposure time was measured using a time-to-event approach (measured in weeks). For each recruit, exposure time began at the BCT class starting date and continued until censored because of an outcome event (an HI), attrition from BCT, or the end of the BCT class, whichever occurred first. Censoring due to attrition was identified by the graduation status variable from ATRRS.

Because BCT classes begin throughout the calendar year, each BCT class experiences unique month-to-month variation in weather-related exposures due to interannual seasonal variation. In order to control for the effect of this variation, data were analyzed by BCT phase and grouped by the month in which recruits started BCT. A recruit was considered to have entered BCT in a given month if their class start date fell within the first 20 days of the month. Recruits whose BCT started on or after the 21st day of a given month were considered to have entered training in the following month.

Statistical analysis

Descriptive analyses included chi-square tests for differences in the outcome frequency distributions by BCT entry-month and site. For BCT site and phase-specific rates, the frequency distribution of outcomes was reported by entry-month and site. Site- and phase-specific incidence rates of HI were calculated as the number of HI cases per 10,000 person-weeks (p-wks) with associated 95% confidence interval (CIs). Rate ratios (RRs) were computed by BCT site and entry-month using Fort Leonard Wood as the reference group because of its northernmost location. Because of low case counts at Fort Leonard Wood during the fall and winter months, RRs are reported for spring and summer months only. P values less than .05 were considered statistically significant. Exact RR estimates, 95% CIs, and mid-p values were calculated using OpenEpi v3.01.[5]

RESULTS

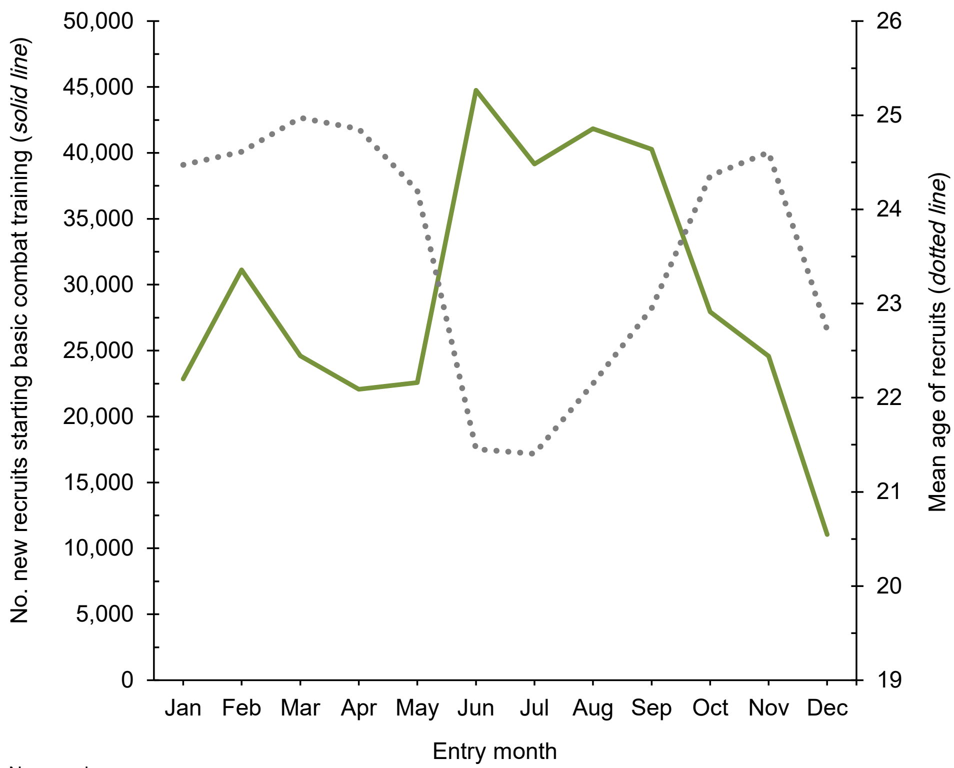
A total of 352,739 recruits entered BCT for the first time during 2014–2018 and were included in the current study **(Table 2)**. Although total annual recruit arrivals varied from year-to-year, the distribution of recruit arrivals by month remained consistent, with an average low of approximately 4,500 recruit arrivals in January to an average high of 9,000 recruit arrivals in June **(data not shown)**. As a result of high school graduation, there is a predictable surge of new and younger recruits entering BCT during the summer months **(Figure 2)**. The BCT population was observed for a total of 3,362,271 p-wks. The mean observed time per recruit was 9.5 weeks (median, 9.7; standard deviation, 0.95; range, 0–10 weeks) **(data not shown)**. A total of 9,159 HIs were reported in the WRIR during the study period among all AD Army service members, of which 13.2% (n=1,210) occurred during BCT. The proportion of recruits without any HI who successfully graduated BCT was 90.0% (n=316,205/351,529) compared to 66.9% (n=809/1,210) of those who were diagnosed with an HI **(data not shown)**. During the 5-year surveillance period, July had the highest total number (n=327) and proportion (27.0%) of HI cases **(Figure 3)**.

TABLE 1. ICD-9/ICD-10 codes used in the heat illness case definition

Condition	ICD-9	ICD-10[a]
Heat stroke	992.0 (heat stroke and sunstroke)	T67.0 (heatstroke and sunstroke)
		T67.0* [A,D,S] (initial, subsequent, or sequela encounter)
Heat exhaustion	992.3 (heat exhaustion, anhydrotic)	T67.3 (heat exhaustion, anhydrotic)
		T67.3* [A,D,S] (initial, subsequent, or sequela encounter)
	992.4 (salt depletion)	T67.4 (heat exhaustion due to salt depletion)
		T67.4* [A,D,S] (initial, subsequent, or sequela encounter)
	992.5 (heat exhaustion, unspecified)	T67.5 (heat exhaustion, unspecified)

[a]An asterisk (*) indicates that any subsequent digit/character is included.
ICD, International Classification of Diseases

FIGURE 2. Cumulative numbers and mean ages, by entry month of basic combat training, U.S. Army recruits, 2014–2018



No., number

TABLE 2. Demographic characteristics of basic combat training population (n=352,739) with results of chi-square tests comparing those with and without a heat illness, U.S. Army recruits, 2014–2018

	All recruits (n=352,739)		Heat illness (%) Yes (n=1,210)		No (n=351,625)		p-value
Sex	N	%	N	%	N	%	
Male	263,891	74.8	674	55.7	263,217	74.9	<.001
Female	88,848	25.2	536	44.3	88,312	25.1	
Race/ethnicity							
Non-Hispanic white	232,499	65.9	721	59.6	231,753	65.9	<.001
Non-Hispanic black	94,582	26.8	416	34.4	94,159	26.8	
Hispanic	22,001	6.2	62	5.1	21,932	6.2	
Asian/Pacific Islander	2,824	0.8	8	0.7	2,816	0.8	
Other/unknown	833	0.2	3	0.2	869	0.2	
Age group (years)							
17–19	46,286	13.1	242	20.0	46,044	13.1	<.001
20–22	137,624	39.0	585	48.3	137,039	39.0	
23–25	90,777	25.7	234	19.3	90,543	25.8	
25+	78,052	22.1	149	12.3	77,903	22.2	
Mean age (SD)	23.2 (3.9)		22.0 (3.3)		23.3 (3.9)		
Service							
Active duty	201,839	57.2	654	54.0	201,185	57.2	<.001
National Guard	100,380	28.5	372	30.7	100,008	28.4	
Reserve	50,520	14.3	184	15.2	50,336	14.3	
Rank							
E1	201,897	57.2	752	62.1	201,145	57.2	<.001
E2	82,164	23.3	326	26.9	81,838	23.3	
E3	39,303	11.1	91	7.5	39,212	11.2	
E4	28,662	8.1	41	3.4	28,621	8.1	
≥E5	713	0.2	0	-	713	0.2	
Training location							
Fort Jackson	185,196	52.5	780	64.5	184,416	52.5	<.001
Fort Sill	77,093	21.9	131	10.8	76,962	21.9	
Fort Leonard Wood	59,124	16.8	94	7.8	59,030	16.8	
Fort Benning	31,326	8.9	205	16.9	31,121	8.9	

SD, standard deviation

The demographic characteristics of all recruits and those affected by an HI are shown in **Table 2**. The rates of HI events were significantly higher among several demographic groups **(Table 3)**. The HI rate was higher among women than men (RR: 2.3) and higher among non-Hispanic black recruits than those in all other race/ethnicity groups. Recruits aged 20 years or older were less likely than those aged 17–19 years to be affected by an HI. Soldiers in the National Guard had slightly increased rates (RR: 1.1) compared to soldiers in the AD component.

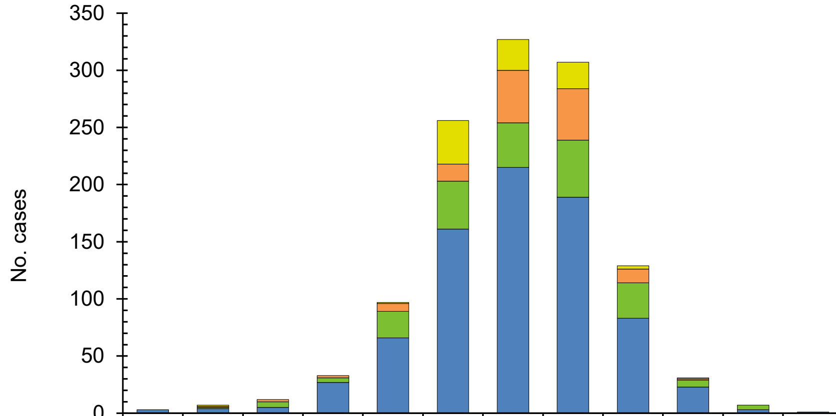
Basic combat training location

Incident HIs were disproportionately distributed among the individual BCT sites, with the highest rate at Fort Benning (6.8 per 10,000 p-wks), followed by Fort Jackson (4.5 per 10,000 p-wks), Fort Sill (1.8 per 10,000 p-wks), and Fort Leonard Wood (1.7 per 10,000 p-wks) **(Table 4)**. Further, recruits who received BCT at Fort Benning had 4.1 (95% CI: 3.2–5.2) times the rate of HI events compared to recruits who received BCT at Fort Leonard Wood. The rate of HI events among Fort Jackson recruits was 2.7 times the rate among Fort Leonard Wood recruits. After controlling for the entry month of BCT, recruits at both Fort Benning and Fort Jackson experienced HI rates that were between 1.9 and 10.3 times the rates among recruits at Fort Leonard Wood for the months of May–August **(Table 5)**. For example, among recruits who started in August, those at Fort Benning experienced 5.9 (95% CI: 3.4–11.2) times the rate of HI events compared to recruits at Fort Leonard Wood.

Basic combat training phase

Of the 1,210 total HIs that occurred during BCT, 686 (56.8%) occurred during phase 1 of training, 277 (22.9%) occurred during phase 2, and 247 (20.4%) occurred during phase 3 **(data not shown)**. The greatest number of incident HI cases occurred in the second week of training **(Figure 4)**, when 23.0% of all HI events occurred **(data not shown)**. In unadjusted analyses, phase 1 of BCT had the highest HI rates at all BCT sites, with 6.5 cases per 10,000 p-wks, followed by phases 2 and 3 with 2.0 and 1.8 cases per 10,000 p-wks, respectively **(data not shown)**. Entering BCT after May was associated with a substantial increase in phase 1 rates and a small reduction in phase 3 rates **(Figure 5)**. After controlling for location, phase, and entry-month, rates varied widely **(Table 6)**. The highest phase 1 rate was 27.1 HIs per 10,000 p-wks for recruits who entered BCT in June at Fort Benning. At Fort Leonard Wood, the highest phase 1 rates were also seen among recruits who entered BCT in June (10.8 per 10,000 p-wks). On the other hand, phase 1 rates at Fort Sill peaked at 9.7 per 10,000 p-wks for those who entered in August, and phase 1 rates at Fort Jackson peaked at 17.7 per 10,000 p-wks for those who entered in July **(Table 6)**.

FIGURE 3. Basic combat training heat illnesses, by month and location, U.S. Army recruits, 2014–2018



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fort Leonard Wood	0	1	0	0	1	38	27	23	3	1	0	0
Fort Sill	0	1	2	2	7	15	46	45	12	1	0	0
Fort Benning	0	1	5	4	23	42	39	50	31	6	4	0
Fort Jackson	3	4	5	27	66	161	215	189	83	23	3	1

No., number

TABLE 3. Heat illness rates and rate ratios, by demographic and military characteristics, U.S. Army recruits, 2014–2018

	Crude HI rate[a]	Rate ratio	95% CI	p-value
Sex				
Male	2.7	ref	-	-
Female	6.4	2.3	(2.1–2.6)	<.001
Race/ethnicity				
Non-Hispanic white	3.3	ref	-	-
Non-Hispanic black	4.6	1.4	(1.2–1.6)	<.001
Hispanic	2.9	0.8	(0.6–1.1)	.425
Asian/Pacific Islander	3.0	0.9	(0.4–1.8)	.799
Other/unknown	3.8	1.1	(0.3–3.5)	.802
Age group (years)				
17–19	5.5	ref	-	-
20–22	4.5	0.8	(0.6–0.9)	.007
23–25	2.7	0.4	(0.4–0.5)	<.001
25+	2.0	0.3	(0.2–0.4)	<.001
Service				
Active duty	3.4	ref	-	-
National Guard	3.9	1.1	(1.0–1.2)	.046
Reserve	3.8	1.1	(0.9–1.3)	.173
Rank				
E1	3.9	ref	-	-
E2	4.2	1.0	(0.9–1.2)	.382
E3	2.4	0.6	(0.4–0.7)	<.001
E4	1.5	0.3	(0.2–0.5)	<.001
≥E5	0.0	n/a	-	-
Training location				
Fort Benning	6.8	4.1	(3.2–5.2)	<.001
Fort Jackson	4.5	2.7	(2.2–3.3)	<.001
Fort Sill	1.8	1.1	(0.8–1.4)	.327
Fort Leonard Wood	1.7	ref	-	-

[a]Number of cases per 10,000 basic combat training person-weeks

HI, heat illness; CI, confidence interval; ref, referent group; n/a, not applicable

EDITORIAL COMMENT

This study examined the timing of HI events among recruits during BCT by month of entry into training and phase of training at each of the 4 BCT locations. HI events occurred at all BCT locations and during all phases of BCT. However, variability in the rates, measured in numbers of HI events per 10,000 p-wks, was seen across BCT sites, BCT entry-month, and BCT training phase. When location was examined, the southernmost locations (Fort Benning and Fort Jackson) had the highest rates of HI events, and rates were significantly higher when compared to the northernmost BCT site (Fort Leonard Wood). This is consistent with the results of a study of active component service members between 2013 and 2017, where Fort Benning and Fort Jackson were among the top 5 Army locations with the highest numbers of HI events.[6]

Despite being located in the southeastern U.S., Fort Benning and Fort Jackson had significantly different HI rates. The quantifiable factors examined in this study did not fully explain this difference. The recruits at these 2 BCT sites experience similar weather environments and training schedules; however, there are many individual risk factors for HI that could not be controlled for in this study. For example, other studies have found that physical fitness, body composition, sex, individual motivation, medication, and prior illness are associated with an increased risk of HI.[1,6–8] While differences in the overall HI injury risk by BCT location have been reported in the past, future investigations into the causes of these differences may benefit from inclusion of environmental and/or local climatological data, factors related to the delivery of training, and care-seeking behavior.[9,10] Another factor that is difficult to control for between BCT sites is diagnostic consistency among medical providers and access to medical care. For example, Fort Benning has an emergency department on the installation; Fort Jackson does not. This may result in considerable and systemic variations in HI diagnosis.

TABLE 4. Heat illness rates and rate ratios, by basic combat training location, U.S. Army recruits, 2014–2018

Location	Crude HI rate[a]	Rate ratio	95% CI	p-value
Fort Benning	6.8	4.1	(3.2–5.2)	<.0001
Fort Jackson	4.5	2.7	(2.2–3.3)	<.0001
Fort Sill	1.8	1.1	(0.8–1.4)	.327
Fort Leonard Wood	1.7	ref	-	-

[a]Number of cases per 10,000 basic combat training person-weeks
HI, heat illness; CI, confidence interval; ref, referent group

TABLE 5. Rate ratios, by basic combat training location and entry month, U.S. Army recruits, 2014–2018

	Entry month	Rate ratio[a]	95% CI	p-value
Fort Benning				
	April	3.2	(0.9–13.0)	.078
	May	10.3	(4.3–29.5)	<.001
	June	3.3	(2.1–5.1)	<.001
	July	1.9	(1.2–3.2)	.010
	August	5.9	(3.4–11.2)	<.001
Fort Jackson				
	April	3.1	(1.2–10.0)	.015
	May	7.1	(3.1–19.6)	<.001
	June	2.1	(1.5–3.1)	<.001
	July	2.4	(1.6–3.7)	<.001
	August	3.3	(2.0–6.0)	<.001
Fort Sill				
	April	0.6	(0.1–2.5)	.426
	May	1.4	(0.5–4.6)	.521
	June	0.6	(0.3–0.9)	.018
	July	1.1	(0.6–1.8)	.831
	August	2.1	(1.2–4.1)	.012

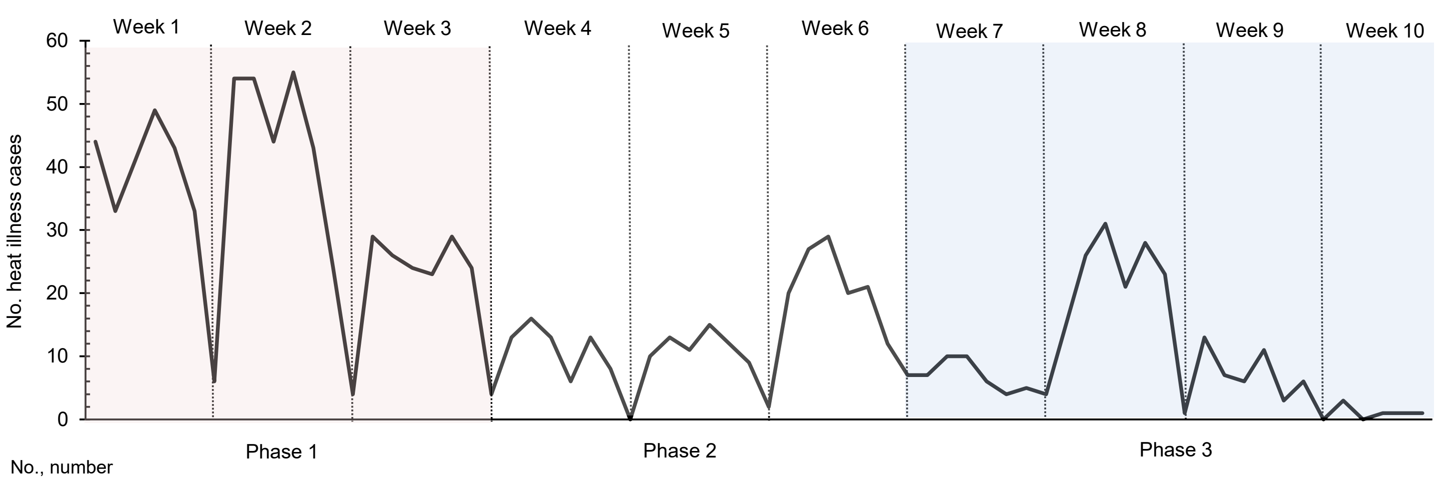
[a]Fort Leonard Wood used as reference
CI, confidence interval

If a recruit entered BCT between May and November, rates of HIs were highest during phase 1. In the later BCT training phases, HI rates were highest among recruits who entered training in May. Each phase is approximately 3 weeks long, so for a recruit entering BCT in May, the later phases of BCT would coincide with the peak summer months of July and August. It is possible that these recruits have adapted to the physical intensity of BCT, but have not been fully acclimatized to hot and humid conditions.

At the time of this report, this was the only study that examined the rate of HI during Army BCT controlling for BCT entry-month and training phase. However, the studies that have been conducted tend to support the results of the current analysis. For example, a study of Army enlisted soldiers found that the highest rates of mild and severe HI occurred within the first 2 months of service; however, this study did not specifically examine the time the enlistees spent in BCT.[1] Moreover, a study of Marine Corps recruits found that the highest number of HI cases occurred during the first 2 weeks of a 12-week recruit training, with a second peak of HI events towards the end of training in weeks 8 and 9,[8] supporting the current report's finding of higher rates of HI during the first few weeks of BCT (phase 1). However, unlike the current study, the Marine study did not consider how seasonal variations in temperature affected the number of HI events.

HI events occurred during each month of the year, but as expected, the majority

FIGURE 4. Daily heat illness case counts, by week and phase of basic combat training, U.S. Army recruits, 2014–2018

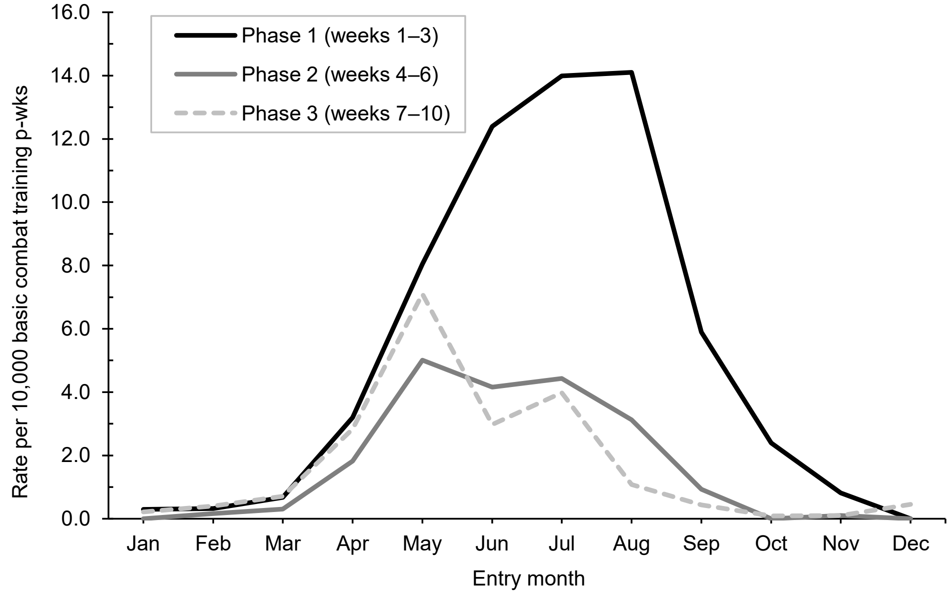


No., number

of HI events at BCT occurred during the summer months (June–August). This is a common finding across the HI literature describing military populations.[1,11,12] Approximately 70,000 recruits entered BCT per calendar year from 2014–2018. The surge of new and younger recruits entering BCT during the hottest months leads to a larger number of recruits completing phase 1 of their training during the period when they are most at risk for an HI.

The findings of this analysis should be interpreted in light of several important limitations. The first potential limitation is the use of U.S. Army administrative data that is not collected or maintained for research purposes to identify the first-time BCT recruits. Despite potential data quality issues with pertinent variables of interest (e.g., training dates) previous research suggests that data sources like the ones used to identify this cohort of likely first-time BCT recruits are valid and consistent with other estimates of the BCT population.[13] The second potential limitation is that while the ICD-9/ICD-10 coding was largely used to define outcomes, a single ICD code may not represent a true or final diagnosis. Moreover, diagnosis coding can be subject to clinician- or site-specific bias and ultimately lead to a potential source of misclassification bias. In order to reduce this bias, the current analysis included only medical records with a code of interest in the first 2 diagnostic code positions. Third, recruits in OSUT, AIT, or basic officer

FIGURE 5. Heat illness rate, by basic combat training phase and entry month, U.S. Army recruits, 2014–2018



P-wks, person-weeks

TABLE 6. Heat illness rates[a], by location, phase, and entry month, U.S. Army recruits, 2014–2018[b]

		Month of entry into basic combat training											
Location	Phase	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fort Benning													
	1 (weeks 1–3)	0.0	0.0	4.9	9.5	18.7	**27.1**	15.1	24.1	22.7	4.8	4.3	0.0
	2 (weeks 4–6)	0.0	1.4	0.0	1.8	6.0	**8.7**	5.1	8.4	1.7	0.0	0.0	0.0
	3 (weeks 7–10)	0.0	0.7	3.7	1.8	**16.8**	9.7	3.6	3.4	1.7	0.7	0.0	0.0
Fort Jackson													
	1 (weeks 1–3)	0.5	0.5	0.5	4.7	10.6	15.5	**17.7**	16.3	7.0	4.1	0.7	0.0
	2 (weeks 4–6)	0.0	0.0	0.4	2.9	**7.2**	5.1	5.8	3.0	1.2	0.0	0.2	0.0
	3 (weeks 7–10)	0.2	0.5	0.8	3.5	**9.7**	3.1	5.9	1.3	0.5	0.0	0.2	0.5
Fort Leonard Wood													
	1 (weeks 1–3)	0.0	0.0	0.0	0.0	0.9	**10.8**	9.7	6.6	0.5	0.0	0.0	0.0
	2 (weeks 4–6)	0.0	0.0	0.0	0.0	**2.1**	1.1	0.8	0.0	0.4	0.0	0.0	0.0
	3 (weeks 7–10)	0.0	0.0	0.0	**3.3**	0.7	2.5	2.4	0.0	0.0	0.0	0.0	0.9
Fort Sill													
	1 (weeks 1–3)	0.0	0.5	0.0	0.0	2.5	2.4	8.4	**9.7**	4.0	0.0	0.0	0.0
	2 (weeks 4–6)	0.0	0.0	0.4	0.5	1.9	3.4	**3.7**	3.2	0.3	0.0	0.0	0.0
	3 (weeks 7–10)	0.5	0.4	0.0	**1.4**	1.4	1.3	1.1	0.3	0.3	0.0	0.0	0.0

[a]Rates are reported per 10,000 basic combat training person-weeks.
[b]Bolded numbers represent peak rates by phase and location.

leadership courses were excluded from this analysis. Although roughly 70% of all new trainees receive BCT as part of their overall IET, the results of this analysis do not represent the complete burden of HI for all service members as evidenced by the fact that the 1,210 HI cases in this study accounted for only 13% (n=1,210/9,159) of all HI cases in Army service members (active component, National Guard, Reserve) during the study period. Fourth, this study did not incorporate climate data (e.g., temperature, humidity, or wind speed) into the analysis. The goal of this study was to identify the differences in HI rates by the timing of BCT entry and BCT phase. The use of climate data in a future analysis could account for short-term (e.g., daily) and long-term (e.g., interannual) variability in local climate and build upon the findings in the current study. Despite these limitations, use of the comprehensive DHA–WRIR data combined with U.S. Army administrative data allowed for a novel level of granularity and insight into the timing and incidence of HI during BCT.

The results of the current study indicate that Fort Benning had the highest rates of HI events, particularly among recruits entering phase 1 training in the summer months (June–August). The rates of HI were lower in the later phases of BCT; however, HI rates increased during BCT phases 2 and 3 among recruits who entered BCT in the spring months (April and May). The identification of periods during the calendar year and within the 10-week training period when rates of HI events are higher could facilitate the targeted implementation of interventions or prevention strategies to mitigate the risk of HI during BCT. Examination of such results by BCT location could inform each site about the time of year when targeted mitigation strategies could be most effective.

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Update: Heat Illness, Active Component, U.S. Armed Forces, 2018

In 2018, there were 578 incident diagnoses of heat stroke and 2,214 incident diagnoses of heat exhaustion among active component service members. The overall crude incidence rates of heat stroke and heat exhaustion diagnoses were 0.45 cases and 1.71 cases per 1,000 person-years, respectively. In 2018, subgroup-specific rates of incident heat stroke diagnoses were highest among males and service members less than 20 years old, Asian/Pacific Islanders, Marine Corps and Army members, recruit trainees, and those in combat-specific occupations. Subgroup-specific incidence rates of heat exhaustion diagnoses in 2018 were notably higher among service members less than 20 years old, Asian/Pacific Islanders, Army and Marine Corps members, recruit trainees, and service members in combat-specific occupations. During 2014–2018, a total of 325 heat illnesses were documented among service members in Iraq and Afghanistan; 8.6% (n=28) were diagnosed as heat stroke. Commanders, small unit leaders, training cadre, and supporting medical personnel must ensure that the military members whom they supervise and support are informed about the risks, preventive countermeasures, early signs and symptoms, and first-responder actions related to heat illnesses.

WHAT ARE THE NEW FINDINGS?

Annual rates of incident heat stroke diagnoses increased steadily between 2014 and 2018. During the same period, the annual incidence rate of heat exhaustion diagnoses peaked in 2018. A sizable proportion of heat stroke and heat exhaustion cases identified through records of ambulatory visits did not prompt mandatory reports through the Reportable Medical Events System.

WHAT IS THE IMPACT ON READINESS AND FORCE HEALTH PROTECTION?

Heat illnesses can degrade U.S. military effectiveness by causing considerable morbidity, particularly during training of recruits and of soldiers and Marines in combat arms specialties. Complete and timely submission of mandatory reports of heat illness events ensures that local public health and command leaders have ready access to real-time surveillance data to identify trends and to guide preventive measures.

Heat illness refers to a group of disorders that occur when the elevation of core body temperature surpasses the compensatory limits of thermoregulation.[1] Heat illness is the result of environmental heat stress and/or exertion and represents a set of conditions that exist along a continuum from less severe (heat exhaustion) to potentially life threatening (heat stroke).

Heat exhaustion is caused by the inability to maintain adequate cardiac output because of strenuous physical exertion and environmental heat stress.[1,2] Acute dehydration often accompanies heat exhaustion but is not required for the diagnosis.[3] The clinical criteria for heat exhaustion include a core body temperature greater than 100.5°F/38°C and less than 104°F/40°C at the time of or immediately after exertion and/or heat exposure, physical collapse at the time of or shortly after physical exertion, and no significant dysfunction of the central nervous system. If any central nervous system dysfunction develops with heat exhaustion (e.g., dizziness or headache), it is mild and rapidly resolves with rest and cooling measures (e.g., removal of unnecessary clothing, relocation to a cooled environment, and oral hydration with cooled, slightly hypotonic solutions).[1–4]

Heat stroke is a debilitating illness characterized clinically by severe hyperthermia (i.e., a core body temperature of 104°F/40°C or greater), profound central nervous system dysfunction (e.g., delirium, seizures, or coma), and additional organ and tissue damage.[1,4,5] The onset of heat stroke requires aggressive clinical treatments, including rapid cooling and supportive therapies such as fluid resuscitation to stabilize organ function.[1,5] The observed pathologic changes in several organ systems are thought to occur through a complex interaction between heat cytotoxicity, coagulopathies, and a severe systemic inflammatory response.[1,5] Multi-organ system failure is the ultimate cause of mortality due to heat stroke.[5]

Timely medical intervention can prevent milder cases of heat illness (e.g., heat exhaustion) from becoming severe (e.g., heat stroke) and potentially life threatening. However, even with medical intervention, heat stroke may have lasting effects, including damage to the nervous system and other vital organs and decreased heat tolerance, making an individual more susceptible to subsequent episodes of heat illness.[6–8] Furthermore, the continued manifestation of multi-organ system dysfunction after heat stroke increases patients' risk of mortality during the ensuing months and years.[9,10]

Strenuous physical activity for extended durations in occupational settings as well as during military operational and training exercises exposes service members to considerable heat stress because of high environmental heat and/or a high rate of metabolic heat production.[11] In some military settings, wearing needed protective clothing or equipment may make it biophysically difficult to dissipate body heat. The resulting body heat burden and associated cardiovascular strain reduce exercise performance and increase the risk of heat-related illness.[11,12]

Over many decades, lessons learned during military training and operations in hot environments as well as a substantial body of literature have resulted in doctrine, equipment, and preventive measures that can significantly reduce the adverse health effects of military activities in hot weather.[13–19] Although numerous effective countermeasures are available, heat-related illness remains a significant threat to the health and operational effectiveness of military members and their units and accounts for considerable morbidity, particularly during recruit training in the U.S. military.[11,20]

In the U.S. Military Health System (MHS), the most serious types of heat-related illness are considered notifiable medical events. Notifiable cases of heat illness include heat exhaustion and heat stroke. All cases of heat illness that require medical intervention or result in change of duty status are reportable.[4]

This report summarizes reportable medical events of heat illness as well as heat illness-related hospitalizations and ambulatory visits among active component service members during 2018 and compares them to the previous 4 years. Episodes of heat stroke and heat exhaustion are summarized separately.

METHODS

The surveillance period was 1 January 2014 through 31 December 2018. The surveillance population included all individuals who served in the active component of the Army, Navy, Air Force, or Marine Corps at any time during the surveillance period. All data used to determine incident heat illness diagnoses were derived from records routinely maintained in the Defense Medical Surveillance System (DMSS). These records document both ambulatory encounters and hospitalizations of active component service members of the U.S. Armed Forces in fixed military and civilian (if reimbursed through the MHS) treatment facilities worldwide. In-theater diagnoses of heat illness were identified from medical records of service members deployed to Southwest Asia or the Middle East and whose healthcare encounters were documented in the Theater Medical Data Store (TMDS). Because heat illnesses 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 any of the service-specific electronic reporting systems; these reports are routinely transmitted and incorporated into the DMSS.

For this analysis, a case of heat illness was defined as an individual with 1) a hospitalization or outpatient medical encounter with a primary (first-listed) or secondary (second-listed) diagnosis of heat stroke (International Classification of Diseases, 9th Revision [ICD-9]: 992.0; International Classification of Diseases, 10th Revision [ICD-10]: T67.0*) or heat exhaustion (ICD-9: 992.3–992.5; ICD-10: T67.3*–T67.5*) or 2) a reportable medical event record of heat exhaustion or heat stroke.[21] Because of an update to the Disease Reporting System internet (DRSi) medical event reporting system in July 2017, the type of reportable medical events for heat illness (i.e., heat stroke or heat exhaustion) could not be distinguished using reportable medical event records in DMSS data. Instead, information on the type of reportable medical event for heat illness during the entire 2014–2018 surveillance period was extracted from the DRSi by the Defense Health Agency (DHA) Army Satellite and Army Public Health Center Staff.

It is important to note that previous *MSMR* analyses included diagnosis codes for other and unspecified effects of heat and light (ICD-9: 992.8 and 992.9; ICD-10: T67.8* and T67.9*) within the heat illness category "other heat illnesses." These codes were excluded from the current analysis and the April 2018 *MSMR* analysis. If an individual had a diagnosis for both heat stroke and heat exhaustion during a given year, only 1 diagnosis was selected, prioritizing heat stroke over heat exhaustion. Encounters for each individual within each calendar year then were prioritized in terms of record source, with hospitalizations prioritized over reportable events, which were prioritized over ambulatory visits.

For surveillance purposes, a "recruit trainee" was defined as an active component service member (grades E1–E4) who was assigned to 1 of the services' 9 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 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 illnesses by military grade overall.

Records of medical evacuations from the U.S. Central Command (CENTCOM) area of responsibility (AOR) (e.g., Iraq or 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 1 inpatient or outpatient heat illness 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.

Medical data from military treatment facilities that are using MHS GENESIS are not available in the DMSS, which was implemented at different sites throughout 2017. These sites include Naval Hospital Oak Harbor, Naval Hospital Bremerton, Air Force Medical Services Fairchild, and Madigan Army Medical Center. Therefore, medical encounter data for individuals seeking care at any of these facilities during 2017–2018 were not included in this analysis.

RESULTS

In 2018, there were 578 incident cases of heat stroke and 2,214 incident cases of heat exhaustion among active component service members **(Table 1)**. The crude overall incidence rates of heat stroke and heat exhaustion diagnoses were 0.45 cases and 1.71 cases per 1,000 person-years (p-yrs), respectively. In 2018, subgroup-specific incidence rates of heat stroke diagnoses were highest among males, those less than 20 years old, Asian/Pacific Islanders, Marine Corps and Army members, recruit trainees, and those in combat-specific occupations **(Table 1)**. The rate of incident heat stroke diagnoses was 20.9% higher among service members in the Marine Corps than among those in the Army; the Army rate was more than 7-fold the Navy rate and 9-fold the Air Force rate; and the rate among females was 26.5% lower than the rate among males. There were only 37 cases of heat stroke reported among recruit trainees, but their incidence rate was more than 3 times that of other enlisted members and officers.

Similar to the heat stroke findings, the crude overall incidence rate of heat exhaustion diagnoses among males was slightly higher than among females **(Table 1)**. In 2018, subgroup-specific rates of incident heat exhaustion diagnoses were notably higher among service members less than 20 years old, Asian/Pacific Islanders, Army and Marine Corps members, recruit trainees, and service members in combat-specific occupations.

Crude (unadjusted) annual incidence rates of heat stroke diagnoses increased steadily from 0.26 cases per 1,000 p-yrs in 2014 to 0.45 cases per 1,000 p-yrs in 2018 **(Figure 1)**. In 2018, there were more heat stroke-related hospitalizations and reportable medical events than in 2017 but similar numbers of ambulatory visits. Crude annual rates of incident heat exhaustion diagnoses increased steadily during the first 3 years of the surveillance period and ranged from a low of 1.12 cases per 1,000 p-yrs in 2014 to 1.42 cases per 1,000 p-yrs in 2016 **(Figure 2)**. Annual rates were stable during 2016–2017 and then increased 18.7% to a peak of 1.71 cases per 1,000 p-yrs in 2018. During the 5-year surveillance period, the numbers of heat exhaustion-related hospitalizations and the proportions they represented remained relatively stable (range: 49–65; 2.7%–3.4%). However, the proportions of of total heat exhaustion cases from reportable medical events increased from 29.5% in 2014 to 40.1% in 2018, while the proportions from ambulatory visits decreased from 66.3% to 57.0% during this period.

TABLE 1. Incident cases[a] and incidence rates[b] of heat illness, active component service members, U.S. Army, Navy, Air Force, and Marine Corps, 2018

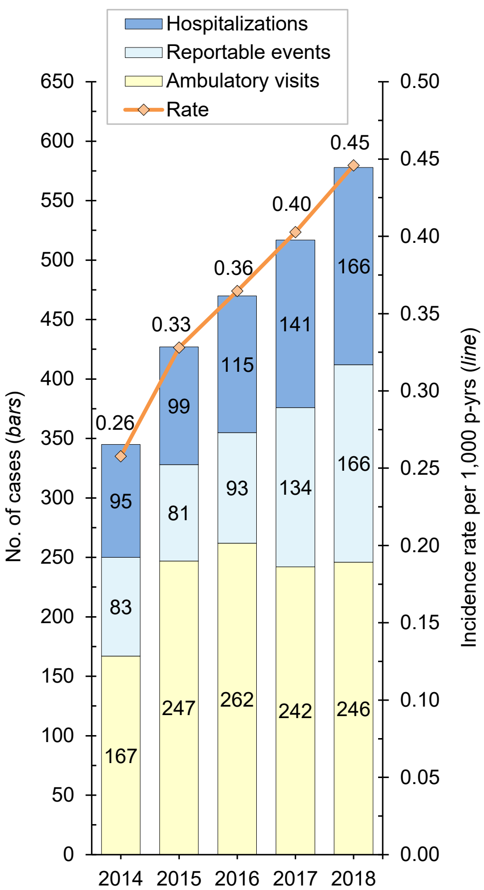
	Heat stroke		Heat exhaustion		Total heat illness diagnoses	
	No.	Rate[b]	No.	Rate[b]	No.	Rate[b]
Total	578	0.45	2,214	1.71	2,792	2.15
Sex						
Male	505	0.47	1,890	1.74	2,395	2.21
Female	73	0.34	324	1.52	397	1.86
Age group (years)						
<20	102	1.00	543	5.34	645	6.34
20–24	246	0.59	1,004	2.41	1,250	3.00
25–29	130	0.44	385	1.29	515	1.73
30–34	60	0.29	165	0.80	225	1.10
35–39	26	0.17	72	0.48	98	0.65
40+	14	0.11	45	0.36	59	0.47
Race/ethnicity						
Non-Hispanic white	330	0.45	1,295	1.77	1,625	2.22
Non-Hispanic black	98	0.47	396	1.90	494	2.36
Hispanic	89	0.43	339	1.64	428	2.07
Asian/Pacific Islander	41	0.76	116	2.14	157	2.89
Other/unknown	20	0.21	68	0.73	88	0.94
Service						
Army	351	0.75	1,361	2.91	1,712	3.67
Navy	33	0.10	121	0.37	154	0.48
Air Force	26	0.08	200	0.62	226	0.71
Marine Corps	168	0.91	532	2.88	700	3.79
Military status						
Recruit	37	1.32	316	11.23	353	12.55
Enlisted	447	0.43	1,723	1.66	2,170	2.09
Officer	94	0.41	175	0.76	269	1.17
Military occupation						
Combat-specific[c]	228	1.29	741	4.20	969	5.50
Motor transport	25	0.66	58	1.53	83	2.19
Pilot/air crew	2	0.04	7	0.15	9	0.19
Repair/engineering	72	0.19	343	0.89	415	1.08
Communications/intelligence	80	0.29	382	1.38	462	1.66
Healthcare	31	0.27	128	1.12	159	1.39
Other/unknown	140	0.54	555	2.14	695	2.68
Home of record[d]						
Midwest	108	0.47	408	1.77	516	2.23
Northeast	90	0.55	265	1.61	355	2.15
South	238	0.43	1,004	1.82	1,242	2.25
West	136	0.44	506	1.65	642	2.10
Other/unknown	6	0.15	31	0.75	37	0.90

[a]One case per person per year
[b]Number of cases per 1,000 person-years
[c]Infantry/artillery/combat engineering/armor
[d]As self-reported at time of entry into service
No., number

Heat illnesses by location

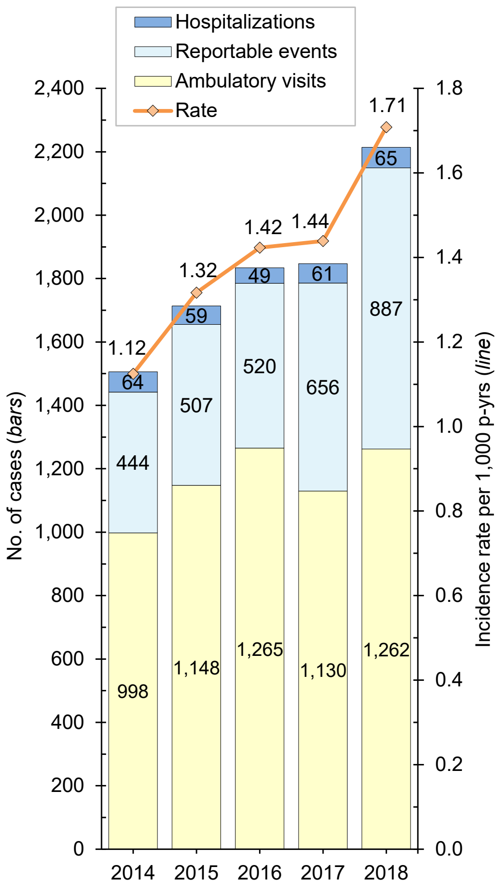
During the 5-year surveillance period, a total of 11,452 heat-related illnesses were diagnosed at more than 250 military installations and geographic locations worldwide **(Table 2)**. Less than 8% of the total heat illness cases occurred outside of the U.S. (n=831). Four Army installations accounted for slightly more than one-third (34.2%) of all heat illnesses during the period (Fort Benning, GA [n=1,504]; Fort Bragg, NC [n=1,108]; Fort Campbell, KY [n=694]; and Fort Polk, LA [n=610]). Six other locations accounted for an additional one-quarter (24.8%) of heat illness events (Marine Corps Base Camp Lejeune/Cherry Point, NC [n=738]; Marine Corps Recruit Depot Parris Island/Beaufort, SC [n=580]; Marine Corps Base Camp Pendleton, CA [n=496]); Naval Medical Center San Diego, CA [n=429]; Okinawa, Japan [n=299]; and Fort Jackson, SC [n=298]). Of these 10

FIGURE 1. Incident cases[a] and incidence rates of heat stroke by source of report and year of diagnosis, active component, U.S. Armed Forces, 2014–2018



[a]Diagnosis codes were prioritized by severity and record source (heat stroke > heat exhaustion; hospitalizations > reportable events > ambulatory visits)
No., number; p-yrs, person-years

FIGURE 2. Incident cases[a] and incidence rates of heat exhaustion, by source of report and year of diagnosis, active component, U.S. Armed Forces, 2014–2018



[a]Diagnosis codes were prioritized by severity and record source (heat stroke > heat exhaustion; hospitalizations > reportable events > ambulatory visits)
No., number; p-yrs, person-years

TABLE 2. Heat injury events[a] by location of diagnosis/report (with at least 100 cases during the period), active component, U.S. Armed Forces, 2014–2018

Location of diagnosis	No.	% total
Fort Benning, GA	1,504	13.1
Fort Bragg, NC	1,108	9.7
MCB Camp Lejeune/Cherry Point, NC	738	6.4
Fort Campbell, KY	694	6.1
Fort Polk, LA	610	5.3
MCRD Parris Island/ Beaufort, SC	580	5.1
MCB Camp Pendleton, CA	496	4.3
NMC San Diego, CA	429	3.7
Okinawa, Japan	299	2.6
Fort Jackson, SC	298	2.6
Fort Hood, TX	272	2.4
Fort Stewart, GA	265	2.3
MCB Quantico, VA	236	2.1
Lackland AFB, TX	198	1.7
Fort Shafter, HI	165	1.4
Fort Leonard Wood, MO	150	1.3
Fort Irwin, CA	111	1.0
Fort Bliss, TX	104	0.9
Fort Sill, OK	103	0.9
All other locations	3,092	27.0
Total	11,452	100.0

[a]One heat injury per person per year
No., number; MCB, Marine Corps Base; MCRD, Marine Corps Recruit Depot; NMC, Naval Medical Center; AFB, Air Force Base

locations with the most heat illness events, 7 are located in the southeastern U.S. The 19 locations with more than 100 cases of heat illness accounted for nearly three-quarters (73.0%) of all active component cases during 2014–2018.

Heat illnesses in Iraq and Afghanistan

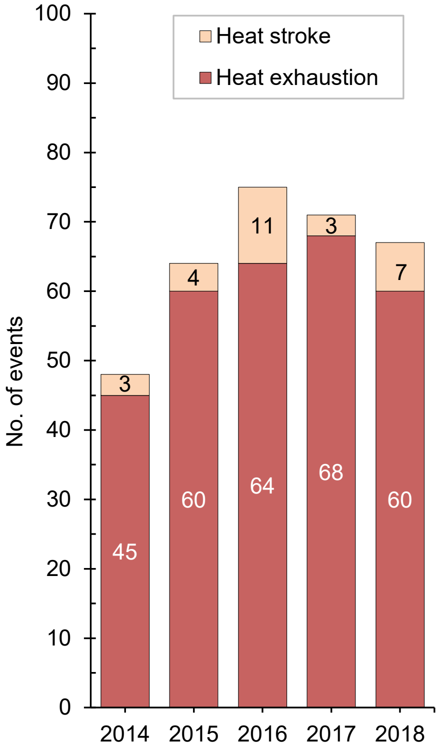
During the 5-year surveillance period, a total of 325 heat illnesses were diagnosed and treated in Iraq and Afghanistan **(Figure 3)**. Of the total cases of heat illness, 8.6% (n=28) were diagnosed as heat stroke. Deployed service members who were affected by heat illnesses were most frequently male (n=270; 83.1%); non-Hispanic white (n=196; 60.3%); 20–24 years old (n=176; 54.2%); in the Army (n=173; 53.2%); enlisted (n=315; 96.9%); and in repair/engineering (n=109; 33.5%) or combat-specific (n=98; 30.2%) occupations **(data not shown)**. During the surveillance period, 4 service members were medically evacuated for heat illnesses from Iraq or Afghanistan; all of the evacuations took place in the summer months (May–September).

EDITORIAL COMMENT

This annual update of heat illnesses among service members in the active component documented that the unadjusted annual rates of incident heat stroke diagnoses increased steadily between 2014 and 2018. The crude annual incidence rate of heat exhaustion diagnoses in 2018 represents an 18.7% increase over the 2017 rate.

There are significant limitations to this update that should be considered when interpreting the results. 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 heat exhaustion events across locations and settings. Also, heat illnesses during training exercises and deployments that are treated

FIGURE 3. Numbers of heat illnesses diagnosed in Iraq/Afghanistan, active component, U.S. Armed Forces, 2014–2018



No., number

in field medical facilities may not be captured in this report. In addition, it should be noted that the guidelines for mandatory reporting of heat illnesses were modified in the 2017 revision of the Armed Forces guidelines and case definitions for reportable medical events.[4] In this updated version of the guidelines and case definitions, the heat injury category was removed, leaving only case classifications for heat stroke and heat exhaustion. 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 using a consistent set of ICD-9/ICD-10 codes for the entire surveillance period. However, it also is important to note that the exclusion of diagnosis codes for other and unspecified effects of heat and light (formerly included within the heat illness category "other heat illnesses") in the current analysis precludes the direct comparison of numbers and rates of cases of heat exhaustion to the numbers and rates of "other heat illnesses" reported in *MSMR* updates prior to 2017.

As has been noted in previous *MSMR* heat illness updates, results indicate that a sizable proportion of cases identified through DMSS records of ambulatory visits did not prompt mandatory reports through the reporting system.[20] However, this study did not directly ascertain the overlap between hospitalizations and reportable events and the overlap between reportable events and outpatient encounters. It is possible that cases of heat illness, whether diagnosed during an inpatient or outpatient encounter, were not documented as reportable medical events because treatment providers were not attentive to the criteria for reporting or because of ambiguity in interpreting the criteria (e.g., the heat illness did not result in a change in duty status or the core body temperature measured during/immediately after exertion or heat exposure was not available). Underreporting is especially concerning for cases of heat stroke because it may reflect insufficient attentiveness to the need for prompt recognition of cases of this dangerous illness and for timely intervention at the local level to prevent additional cases.

In spite of its limitations, this report documents that heat illnesses are a significant and persistent threat to both 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 illnesses, 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 the military members whom they supervise and support are informed regarding the risks, preventive countermeasures (e.g., water consumption), early signs and symptoms, and first-responder actions related to heat illnesses.[13–19,22] 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 illnesses.

Policies, guidance, and other information related to heat illness prevention and treatment among U.S. military members are available online at https://phc.amedd.army.mil/topics/discond/hipss/Pages/Heat-Related-Illness-Prevention.aspx.

Acknowledgment: The authors thank the Army Public Health Center, Aberdeen, MD, for providing data on reportable medical events of heat illnesses.

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Update: Exertional Rhabdomyolysis, Active Component, U.S. Armed Forces, 2014–2018

CE/CME This article provides continuing education (CE) and continuing medical education (CME) credit. Please see information at the end of the article.

Among active component service members in 2018, there were 545 incident diagnoses of rhabdomyolysis likely due to exertional rhabdomyolysis, for an unadjusted incidence rate of 42.0 cases per 100,000 person-years. Subgroup-specific rates in 2018 were highest among males, those less than 20 years old, Asian/Pacific Islander service members, Marine Corps and Army members, and those in combat-specific or "other/unknown" occupations. During 2014–2018, crude rates of exertional rhabdomyolysis increased steadily from 2014 through 2016 after which rates declined slightly in 2017 before increasing again in 2018. Compared to service members in other race/ethnicity groups, the overall rate of exertional rhabdomyolysis was highest among non-Hispanic blacks in every year except 2018. Overall and annual rates were highest among Marine Corps members, intermediate among those in the Army, and lowest among those in the Air Force and Navy. Most cases of exertional rhabdomyolysis were diagnosed at installations that support basic combat/recruit training or major ground combat units of the Army or the Marine Corps. 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.

WHAT ARE THE NEW FINDINGS?

The annual numbers and rates of diagnoses of exertional rhabdomyolysis among active component U.S. military members during the 2014–2018 period peaked in 2018. In 2018, for the first time, the annual rate of exertional rhabdomyolysis among Asian/Pacific Islanders was higher than the rate in any other race/ethnicity group.

WHAT IS THE IMPACT ON READINESS AND FORCE HEALTH PROTECTION?

The net increase in annual rates of exertional rhabdomyolysis suggests that Commanders, supervisors, and trainers at recruit training camps and at installations with large ground combat units need to be more aggressive in preventing cases of this and other types of heat injury and in detecting early signs of such serious heat-associated injuries.

Rhabdomyolysis is characterized by the breakdown of skeletal muscle cells and the subsequent release of intracellular muscle contents into the circulation. The characteristic triad of rhabdomyolysis includes weakness, myalgias, and red to brown urine (due to myoglobinuria) accompanied by an elevated serum concentration of creatine kinase.[1,2] In exertional rhabdomyolysis, damage to skeletal muscle is generally caused by high-intensity, protracted, or repetitive physical activity, usually after engaging in unaccustomed strenuous exercise (especially with eccentric and/or muscle-lengthening contractions).[3] Even athletes who are used to intense training and who are being carefully monitored are at risk of this condition,[4] especially if new overexertion-inducing exercises are being introduced.[5] Illness severity ranges from elevated serum muscle enzyme levels without clinical symptoms to life-threatening disease associated with extreme enzyme elevations, electrolyte imbalances, and kidney failure.[1–3,6]

Risk factors for exertional rhabdomyolysis include younger age, male sex, a lower level of physical fitness, a prior heat illness, a lower level of education, and exertion during the warmer months of the year.[1,3,7–10] Acute kidney injury, due to an excessive concentration of free myoglobin in the urine accompanied by volume depletion, renal tubular obstruction, and renal ischemia, represents a serious complication of rhabdomyolysis.[6,11] Severly affected patients can also develop compartment syndrome, fever, dysrhythmias, metabolic acidosis, and altered mental status.

In U.S. military members, rhabdomyolysis is a significant threat during physical exertion, particularly under heat stress.[7,9,12–14] Moreover, although rhabdomyolysis can affect any service member, new recruits, who are not yet accustomed to the physical exertion required of basic training, may be at particular risk.[9] Each year, the *MSMR* summarizes the numbers, rates, trends, risk factors, and locations of occurrences of exertional heat injuries, including exertional rhabdomyolysis. This report includes the data for 2014–2018. Additional information about the definition, causes, and prevention of exertional rhabdomyolysis can be found in previous issues of the *MSMR*.[12,13,15]

METHODS

The surveillance period was 1 January 2014 through 31 December 2018. The surveillance population included all individuals who served in the active component of the Army, Navy, Air Force, or Marine Corps at any time during the surveillance period. All data used to determine incident exertional rhabdomyolysis diagnoses were derived from records routinely maintained in the Defense Medical Surveillance System (DMSS). These records document both ambulatory encounters and hospitalizations of active component members of the U.S. Armed Forces in fixed military and civilian (if reimbursed through the Military Health System [MHS]) treatment facilities worldwide. In-theater diagnoses of exertional rhabdomyolysis were identified from medical records of service members deployed to Southwest Asia/Middle East and whose healthcare encounters were documented in the Theater Medical Data Store (TMDS).

For this analysis, a case of exertional rhabdomyolysis was defined as an individual with 1) a hospitalization or outpatient medical encounter with a diagnosis in any position of either "rhabdomyolysis" (International Classification of Diseases, 9th Revision [ICD-9]: 728.88; International Classification of Diseases, 10th Revision [ICD-10]: M62.82) or "myoglobinuria" (ICD-9: 791.3; ICD-10: R82.1) plus a diagnosis in any position of 1 of the following: "volume depletion (dehydration)" (ICD-9: 276.5*; ICD-10: E86.0, E86.1, E86.9), "effects of heat" (ICD-9: 992.0–992.9; ICD-10: T67.0–T67.9), "effects of thirst (deprivation of water)" (ICD-9: 994.3; ICD-10: T73.1), "exhaustion due to exposure" (ICD-9: 994.4; ICD-10: T73.2), or "exhaustion due to excessive exertion (overexertion)" (ICD-9: 994.5; ICD-10: T73.3).[13] Each individual could be considered an incident case of exertional rhabdomyolysis 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; ICD-10: S00–T88, except the codes specific for "sprains and strains of joints and adjacent muscles" and "effects of heat, thirst, and exhaustion") were not considered indicative of exertional rhabdomyolysis.[13]

For surveillance purposes, a "recruit trainee" was defined as an active component member in an enlisted grade (E1–E4) who was assigned to 1 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.

In-theater diagnoses of exertional rhabdomyolysis were analyzed separately; however, the same case-defining criteria and incidence rules were applied to identify incident cases. Records of medical evacuations from the U.S. Central Command (CENTCOM) area of responsibility (AOR) (e.g., Iraq and Afghanistan) to a medical treatment facility outside the CENTCOM AOR also 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.

The new electronic health record for the MHS, MHS GENESIS, was implemented at several military treatment facilities during 2017. Medical data from sites that are using MHS GENESIS are not available in the DMSS. These sites include Naval Hospital Oak Harbor, Naval Hospital Bremerton, Air Force Medical Services Fairchild, and Madigan Army Medical Center. Therefore, medical encounters for individuals seeking care at any of these facilities during 2017–2018 were not included in this analysis.

RESULTS

In 2018, there were 545 incident diagnoses of rhabdomyolysis likely associated with physical exertion and/or heat stress (exertional rhabdomyolysis) **(Table 1)**. The crude (unadjusted) incidence rate was 42.0 cases per 100,000 person-years (p-yrs). Subgroup-specific incidence rates of exertional rhabdomyolysis diagnoses were highest among males (45.9 per 100,000 p-yrs), those less than 20 years old (86.1 per 100,000 p-yrs), Asian/Pacific Islander service members (73.8 per 100,000 p-yrs), Marine Corps and Army members (99.0 per 100,000 p-yrs and 54.8 per 100,000 p-yrs, respectively), and those in combat-specific or "other/unknown" occupations (76.0 per 100,000 p-yrs and 72.9 per 100,000 p-yrs, respectively) **(Table 1)**. Of note, the incidence rate among recruit trainees was more than 6 times that among other enlisted members and officers, even though cases among this group accounted for only 13.0% of all cases in 2018.

During the surveillance period, crude annual rates of incident diagnoses of exertional rhabdomyolysis increased steadily from 30.0 per 100,000 p-yrs in 2014 to 40.8 per 100,000 p-yrs in 2016 after which rates declined slightly to 39.0 per 100,000 p-yrs in 2017 before increasing again to 42.0 per 100,000 p-yrs in 2018 **(Figure 1)**. During 2014–2018, the annual incidence rates of exertional rhabdomyolysis diagnoses were highest among non-Hispanic blacks in every year except 2018, when the highest rate occurred among Asian/Pacific Islanders **(data not shown)**. Overall and annual rates of incident exertional rhabdomyolysis diagnoses were highest among service members in the Marine Corps, intermediate among those in the Army, and lowest among those in the Air Force and Navy **(Table 1, Figure 2)**. The most pronounced increases in annual incidence rates were observed among Marine Corps members and Army members during 2014–2016 (35.5% and 46.2%, respectively); however, rates among service members in the Air Force and Navy remained relatively stable **(Figure 2)**. During the surveillance period, approximately three-quarters (75.6%) of the cases occurred during May–October **(Figure 3)**.

Rhabdomyolysis by location

During the 5-year surveillance period, the medical treatment facilities at 11

TABLE 1. Incident diagnoses and incidence rates[a] of exertional rhabdomyolysis, active component, U.S. Armed Forces, 2018

	Hospitalizations		Ambulatory visits		Total	
	No.	Rate[a]	No.	Rate[a]	No.	Rate[a]
Total	260	20.1	285	22.0	545	42.0
Sex						
Male	234	21.6	263	24.3	497	45.9
Female	26	12.2	22	10.3	48	22.5
Age group (years)						
<20	66	35.7	93	50.3	159	86.1
20–24	86	25.8	68	20.4	154	46.2
25–29	47	15.8	75	25.1	122	40.9
30–34	38	18.5	29	14.1	67	32.7
35–39	17	11.3	11	7.3	28	18.7
40+	6	4.8	9	7.2	15	12.0
Race/ethnicity						
Non-Hispanic white	114	15.6	135	18.4	249	34.0
Non-Hispanic black	67	32.1	70	33.5	137	65.6
Hispanic	42	20.3	47	22.7	89	43.0
Asian/Pacific Islander	22	40.6	18	33.2	40	73.8
Other/unknown	15	16.1	15	16.1	30	32.1
Service						
Army	109	23.3	147	31.5	256	54.8
Navy	31	9.6	17	5.2	48	14.8
Air Force	37	11.5	21	6.6	58	18.1
Marine Corps	83	44.9	100	54.1	183	99.0
Military status						
Enlisted	192	18.5	209	20.1	401	38.6
Officer	37	16.1	36	15.7	73	31.7
Recruit	31	108.5	40	140.0	71	248.5
Military occupation						
Combat-specific[b]	51	28.9	83	47.1	134	76.0
Motor transport	10	26.3	9	23.7	19	50.0
Pilot/air crew	3	6.5	0	0.0	3	6.5
Repair/engineering	53	13.8	42	10.9	95	24.7
Communications/intelligence	29	10.4	44	15.8	73	26.3
Healthcare	22	19.3	10	8.8	32	28.1
Other/unknown	92	35.5	97	37.4	189	72.9
Home of record						
Midwest	35	15.2	44	19.1	79	34.2
Northeast	44	26.7	40	24.3	84	50.9
South	116	21.0	135	24.4	251	45.4
West	61	19.9	56	18.3	117	38.2
Other/unknown	4	9.7	10	24.2	14	33.8

[a]Rate per 100,000 person-years
[b]Infantry/artillery/combat engineering/armor
[c]As self-reported at time of entry into service
No., number

installations diagnosed at least 50 cases each; when combined, these installations diagnosed almost half (47.7%) of all cases **(Table 2)**. Of these 11 installations, 4 provide support to recruit/basic combat training centers (Marine Corps Recruit Depot Parris Island/Beaufort, SC; Fort Benning, GA; Joint Base San Antonio–Lackland, TX; and Fort Leonard Wood, MO). In addition, 6 installations support large combat troop populations (Fort Bragg, NC; Marine Corps Base [MCB] Camp Pendleton, CA; MCB Camp Lejeune/Cherry Point, NC; Fort Shafter, HI; Fort Hood, TX; and Fort Campbell, KY). The most cases overall were diagnosed at Fort Bragg, NC (n=272) and MCRD Parris Island/Beaufort, SC (n=250), which together accounted for more than one-fifth (22.5%) of all cases **(Table 2)**.

Rhabdomyolysis in Iraq and Afghanistan

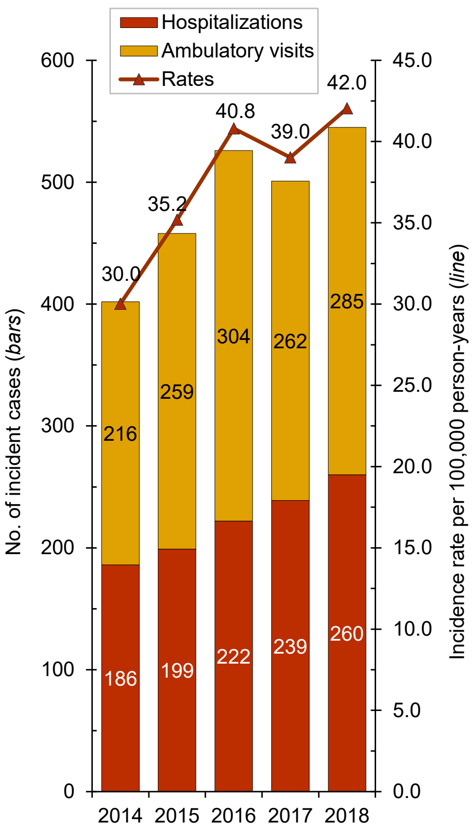
There were 6 incident cases of exertional rhabdomyolysis diagnosed and treated in Iraq/Afghanistan **(data not shown)** during the 5-year surveillance period. Deployed service members who were affected by exertional rhabdomyolysis were more often non-Hispanic black or non-Hispanic white (n=4; 66.7% and n=2; 33.3%, respectively), male (n=6), aged 20–24 years (n=2; 33.3%), in the Army (n=6), enlisted (n=6), and in communication/intelligence occupations (n=2; 33.3%). One active component service member was medically evacuated from Iraq/Afghanistan for exertional rhabdomyolysis; this medical evacuation occurred in September 2015 **(data not shown)**.

EDITORIAL COMMENT

This report documents an increase in the crude annual incidence rates of diagnoses of exertional rhabdomyolysis among active component U.S. military members from 2014 through 2016 after which rates declined slightly in 2017 before increasing again in 2018. 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.

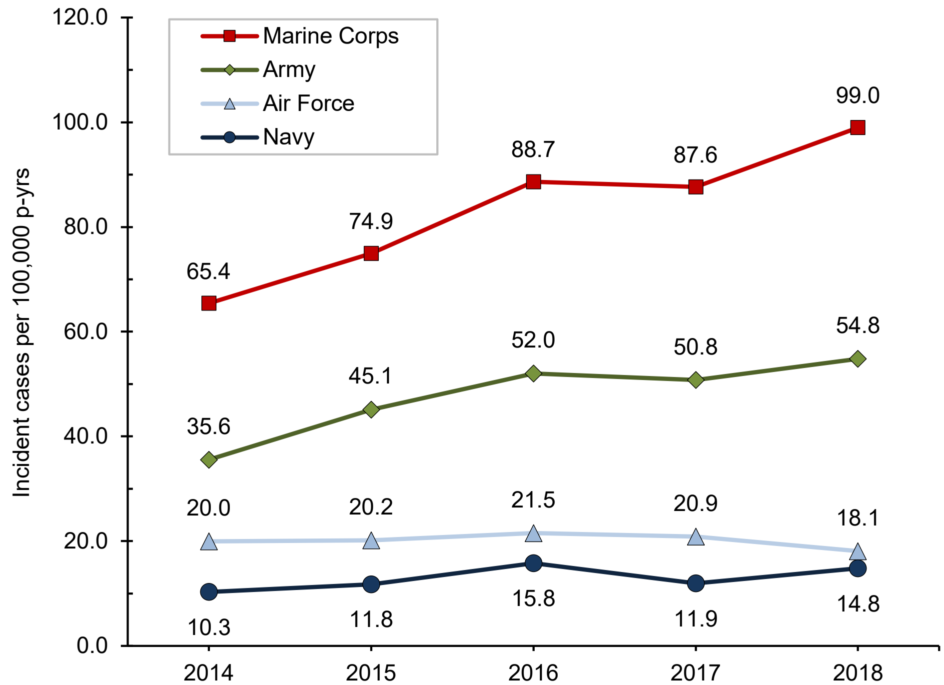
The risks of heat injuries, including exertional rhabdomyolysis, are increased among individuals who suddenly increase overall levels of physical activity, recruits who are not physically fit when they begin training, and recruits from relatively cool and dry climates who may not be acclimated to the high heat and humidity at training camps in the summer.[1,2,9] Soldiers and Marines in combat units often conduct rigorous unit physical training,

FIGURE 1. Incident cases of exertional rhabdomyolysis by year, active component, U.S. Armed Forces, 2014–2018



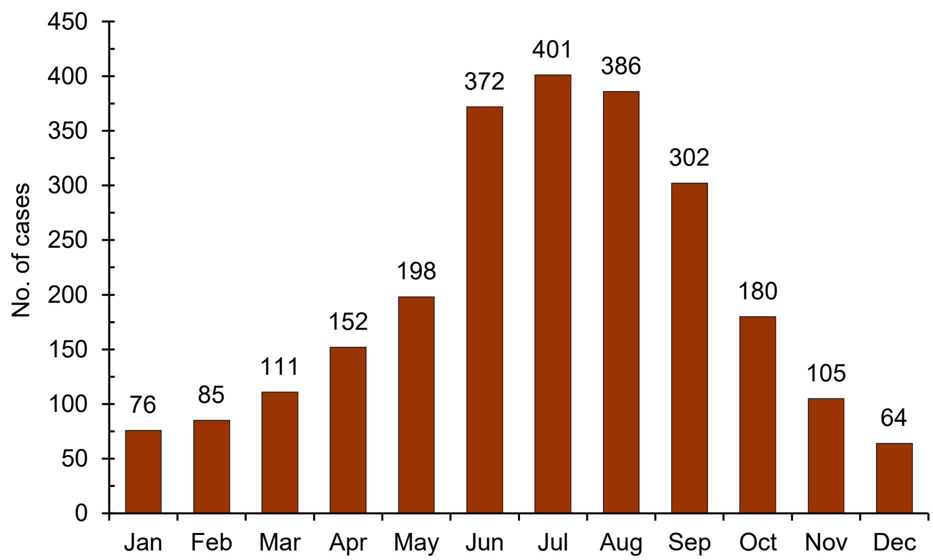
No., number; p-yrs, person-years

FIGURE 2. Annual incidence rates of exertional rhabdomyolysis by service, active component, U.S. Armed Forces, 2014–2018



P-yrs, person-years

FIGURE 3. Distribution of exertional rhabdomyolosis cases by month, 2014–2018



No., number

personal fitness training, and field training exercises regardless of weather conditions. Thus, it is not surprising that recruit camps and installations with large ground combat units account for most of the cases of exertional rhabdomyolysis.

The annual incidence rates among non-Hispanic black service members were higher than the rates among members of other race/ethnicity groups in 4 of the 5 previous years, with the exception of 2018. This observation has been attributed, at least in part, to an increased risk of exertional rhabdomyolysis among individuals with sickle cell trait[16–19] and is supported by at least 1 other study among U.S. service members.[9] However, in 2018, the rate among Asian/Pacific Islanders was the highest of all race/ethnicity groups. Although the annual incidence rates of exertional rhabdomyolysis for service members in this group have been increasing since 2009, the reasons for such a trend are unknown. Supervisors at all levels should ensure 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/ICD-10

TABLE 2. Incident cases of exertional rhabdomyolysis by installation (with at least 30 cases during the period), active component, U.S. Armed Forces, 2014–2018

Location of diagnosis	No.	% total
Fort Bragg, NC	272	11.2
MCRD Parris Island/ Beaufort, SC	250	10.3
MCB Camp Pendleton, CA	133	5.5
Fort Benning, GA	128	5.3
MCB Camp Lejeune/ Cherry Point, NC	112	4.6
Fort Shafter, HI	83	3.4
JBSA-Lackland AFB, TX	70	2.9
Fort Hood, TX	67	2.8
Fort Campbell, KY	61	2.5
Fort Leonard Wood, MO	57	2.3
Fort Carson, CO	54	2.2
NMC San Diego, CA	49	2.0
Fort Gordon, GA	46	1.9
Fort Bliss, TX	38	1.6
Fort Belvoir, VA	38	1.6
Fort Stewart, GA	36	1.5
Fort Jackson, SC	35	1.4
Okinawa, Japan	34	1.4
Fort Polk, LA	31	1.3
NMC Portsmouth, VA	31	1.3
Other/unknown locations	807	33.2
Total	2,432	100.0

No., number; MCRD, Marine Corps Recruit Depot; MCB, Marine Corps Base; JBSA, Joint Base San Antonio; AFB, Air Force Base; NMC, Naval Medical Center

diagnostic codes related to rhabdomyolysis with additional codes indicative of the effects of exertion, heat, or dehydration. Furthermore, other ICD-9/ICD-10 codes were used to exclude cases of rhabdomyolysis that may have been 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 risk of exertional rhabdomyolysis can be reduced by emphasizing graded, individual preconditioning before starting a more strenuous exercise program and by adhering to recommended work/rest and hydration schedules, especially in hot weather. The physical activities of overweight and/or previously sedentary new recruits should be closely monitored. 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).[8]

Management after treatment for exertional rhabdomyolysis, including the decision to return to physical activity and duty, is a persistent challenge among athletes and military members.[9,10,20] It is recommended that those who have had a clinically confirmed exertional rhabdomyolysis event be further evaluated and risk stratified for recurrence before return to activity/duty.[10,21,22] Low-risk patients may gradually return to normal activity levels, while those deemed high risk for recurrence will require further evaluative testing (e.g., genetic testing for myopathic disorders).[20,21]

Commanders and supervisors at all levels should watch for early signs of exertional heat injuries and should intervene aggressively 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.

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CE/CME

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Key points

- The unadjusted overall incidence rate of exertional rhabdomyolysis diagnoses among active component service members in 2018 was 42.0 cases per 100,000 person-years. Subgroup-specific overall rates in 2018 were highest among males, those less than 20 years old, Asian/Pacific Islander service members, Marine Corps and Army members, and those in combat-specific or "other/unknown" occupations.
- During 2014–2018, crude annual rates of incident exertional rhabdomyolysis diagnoses increased steadily from 2014 through 2016 after which rates declined slightly in 2017 before increasing again in 2018; compared to service members in other race/ethnicity groups, the annual rates of exertional rhabdomyolysis were highest among non-Hispanic blacks in every year except 2018.
- Overall and annual rates of incident exertional rhabdomyolysis were highest among Marine Corps members, intermediate among those in the Army, and lowest among those in the Air Force and Navy.

Learning objectives

1. The reader will analyze recent trends in the rates of incident exertional rhabdomyolysis diagnoses among active component service members.
2. The reader will explain how incidence rates of exertional rhabdomyolysis diagnoses among active component service members of different race/ethnicities compare over the surveillance period.
3. The reader will identify risk factors for and signs of exertional rhabdomyolysis as well as ways to reduce the risk of rhabdomyolysis among service members.

Disclosures: MSMR editorial staff engage in a monthly collaboration with the DHA J7 Continuing Education Program Office (CEPO) to provide this CE/CME activity. MSMR staff authors, the DHA J7 CEPO, as well as the planners and reviewers of this activity have no financial or nonfinancial interest to disclose.

Update: Exertional Hyponatremia, Active Component, U.S. Armed Forces, 2003–2018

From 2003 through 2018, there were 1,579 incident diagnoses of exertional hyponatremia among active component service members, for a crude overall incidence rate of 7.2 cases per 100,000 person-years (p-yrs). Compared to their respective counterparts, females, those less than 20 years old, and recruit trainees had higher overall incidence rates of exertional hyponatremia diagnoses. The overall incidence rate during the 16-year period was highest in the Marine Corps, intermediate in the Army and Air Force, and lowest in the Navy. Overall rates during the surveillance period were highest among Asian/Pacific Islander and non-Hispanic white service members and lowest among non-Hispanic black service members. Between 2003 and 2018, crude annual incidence rates of exertional hyponatremia peaked in 2010 (12.7 per 100,000 p-yrs) and then decreased to 5.3 cases per 100,000 p-yrs in 2013 before increasing in 2014 and 2015. The crude annual rate in 2018 (6.3 per 100,000 p-yrs) represented a decrease of 26.5% from 2015. 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, and recreational activities) in hot, humid weather.

WHAT ARE THE NEW FINDINGS?

During 2003–2018, annual numbers and rates of diagnoses of exertional hyponatremia among active component U.S. military members were relatively stable from year to year with the exception of 2009–2011 when rates were dramatically higher. Overall incidence rates of exertional hyponatremia by subgroups of demographic and military characteristics were generally similar to those reported in previous *MSMR* updates.

WHAT IS THE IMPACT ON READINESS AND FORCE HEALTH PROTECTION?

Exertional hyponatremia continues to pose a health risk to U.S. military members and can significantly impair performance and reduce combat effectiveness. Military members (particularly recruit trainees and women) and their supervisors must be vigilant for early signs of heat-related illnesses, intervene immediately and appropriately (but not excessively) in such cases, and heed the recently validated guidance on fluid intake.

Exertional (or exercise-associated) hyponatremia refers to a low serum, plasma, or blood sodium concentration (below 135 milliequivalents/liter) that develops during or up to 24 hours following prolonged physical activity.[1] Acute hyponatremia creates an osmotic imbalance between fluids outside and inside of cells. This osmotic gradient causes water to flow from outside to inside the cells of various organs, including the lungs (which can cause pulmonary edema) and brain (which can cause cerebral edema), producing serious and sometimes fatal clinical effects.[1,2] Swelling of the brain increases intracranial pressure, which can decrease cerebral blood flow and disrupt brain function, potentially causing hypotonic encephalopathy, seizures, or coma. Rapid and definitive treatment is needed to relieve increasing intracranial pressure and prevent brain stem herniation, which can result in respiratory arrest.[2–4]

Serum sodium concentration is determined mainly by the total content of exchangeable body sodium and potassium relative to total body water. Thus, exertional hyponatremia can result from loss of sodium and/or potassium, a relative excess of body water, or a combination of both.[5,6] However, overconsumption of fluids and the resultant excess of total body water are the primary driving factors in the development of exertional hyponatremia.[1,7,8] Other important factors include the persistent secretion of antidiuretic hormone (arginine vasopressin), excessive sodium losses in sweat, and inadequate sodium intake during prolonged physical exertion, particularly during heat stress.[2–4,9] The importance of sodium losses through sweat in the development of exertional hyponatremia is influenced by the fitness level of the individual. Less fit individuals generally have a higher sweat sodium concentration, a higher rate of sweat production, and an earlier onset of sweating during exercise.[10–12]

This report uses a surveillance case definition for exertional hyponatremia to estimate the frequencies, rates, trends, geographic locations, and demographic and military characteristics of exertional hyponatremia cases among U.S. military members from 2003 through 2018.[13]

METHODS

The surveillance period was 1 January 2003 through 31 December 2018. The surveillance population included all individuals who served in an active component of the U.S. Army, Navy, Air Force, or Marine Corps at any time during the surveillance period. All data used to determine incident exertional hyponatremia diagnoses were derived from records routinely maintained in the Defense Medical Surveillance System (DMSS). These records document both ambulatory encounters and hospitalizations of active component service members of the U.S. Armed Forces in fixed military and civilian (if reimbursed through the Military Health System [MHS]) treatment facilities worldwide. In-theater diagnoses of hyponatremia were identified from medical records of service members deployed to Southwest Asia/Middle East and whose healthcare encounters were documented in the Theater Medical Data Store (TMDS). TMDS records became available in the DMSS beginning in 2008.

For this analysis, a case of exertional hyponatremia was defined as 1) a hospitalization or ambulatory visit with a primary (first-listed) diagnosis of "hypo-osmolality and/or hyponatremia" (International Classification of Diseases, 9th Revision [ICD-9]: 276.1; International Classification of Diseases, 10th Revision [ICD-10]: E87.1) and no other illness or injury-specific diagnoses (ICD-9: 001–999) in any diagnostic position or 2) both a diagnosis of "hypo-osmolality and/or hyponatremia" (ICD-9: 276.1; ICD-10: E87.1) and at least 1 of the following within the first 3 diagnostic positions: "fluid overload" (ICD-9: 276.9; ICD-10: E87.70, E87.79), "alteration of consciousness" (ICD-9: 780.0*; ICD-10: R40.*), "convulsions" (ICD-9: 780.39; ICD-10: R56.9), "altered mental status" (ICD-9: 780.97; ICD-10: R41.82), "effects of heat/light" (ICD-9: 992.0–992.9; ICD-10: T67.0*–T67.9*), or "rhabdomyolysis" (ICD-9: 728.88; ICD-10: M62.82).[13]

Medical encounters were not considered case-defining events if the associated records included the following diagnoses in any diagnostic position: alcohol/illicit drug abuse; psychosis, depression, or other major mental disorders; endocrine (e.g., pituitary or adrenal) disorders; kidney diseases; intestinal infectious diseases; cancers; major traumatic injuries; or complications of medical care. Each individual could be considered an incident case of exertional hyponatremia 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 1 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 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.

In-theater diagnoses of exertional hyponatremia were analyzed separately using the same case-defining criteria and incidence rules that were applied to identify incident cases at fixed treatment facilities. Records of medical evacuations from the U.S. Central Command (CENTCOM) area of responsibility (AOR) (e.g., Iraq and 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.

The new electronic health record for the MHS, MHS GENESIS, was implemented at several military treatment facilities during 2017. Medical data from sites that are using MHS GENESIS are not available in the DMSS. These sites include Naval Hospital Oak Harbor, Naval Hospital Bremerton, Air Force Medical Services Fairchild, and Madigan Army Medical Center. Therefore, medical encounter data for individuals seeking care at any of these facilities during 2017–2018 were not included in this analysis.

RESULTS

During 2003–2018, permanent medical facilities recorded 1,579 incident diagnoses of exertional hyponatremia among active component service members, for a crude overall incidence rate of 7.2 cases per 100,000 person-years (p-yrs) **(Table 1)**. In 2018, there were 82 incident diagnoses of exertional hyponatremia (incidence rate: 6.3 per 100,000 p-yrs) among active component service members. During this year, males represented 85.4% of exertional hyponatremia cases (n=70); the annual incidence rate was slightly higher among males (6.5 per 100,000 p-yrs) than females (5.6 per 100,000 p-yrs) **(Table 1)**. The highest age group-specific annual incidence rates in 2018 were among the youngest (less than 20 years old) service members. Although the Army had the most cases during 2018 (n=29), the

TABLE 1. Incident cases[a] and rates[b] of hyponatremia/overhydration diagnoses, active component, U.S. Armed Forces, January 2003–December 2018

	2018		Total 2003–2018	
	No.	Rate[b]	No.	Rate[b]
Total	82	6.3	1,579	7.2
Sex				
Male	70	6.5	1,317	7.1
Female	12	5.6	262	8.1
Age group (years)				
<20	14	13.8	204	13.6
20–24	22	5.3	498	7.0
25–29	14	4.7	282	5.6
30–34	16	7.8	177	5.4
35–39	7	4.7	181	7.0
40+	9	7.2	237	10.4
Race/ethnicity				
Non-Hispanic white	44	6.0	1,070	8.1
Non-Hispanic black	16	7.7	195	5.4
Hispanic	13	6.3	157	5.8
Asian/Pacific Islander	5	9.2	68	8.3
Other/unknown	4	4.3	89	6.2
Service				
Army	29	6.2	553	6.8
Navy	21	6.5	254	4.8
Air Force	12	3.7	315	5.9
Marine Corps	20	10.8	457	15.2
Military status				
Recruit	11	39.1	143	31.9
Enlisted	56	5.4	1,110	6.3
Officer	15	6.5	326	8.9
Military occupation				
Combat-specific[c]	20	11.3	264	8.5
Motor transport	3	7.9	33	5.1
Pilot/air crew	3	6.5	48	5.8
Repair/engineering	13	3.4	286	4.5
Communications/intelligence	17	6.1	278	5.7
Healthcare	4	3.5	119	6.4
Other/unknown	22	8.5	551	13.4
Home of record[d]				
Midwest	15	6.5	299	7.4
Northeast	8	4.9	232	8.2
South	39	7.1	668	7.4
West	19	6.2	302	6.2
Other/unknown	1	2.4	78	7.8

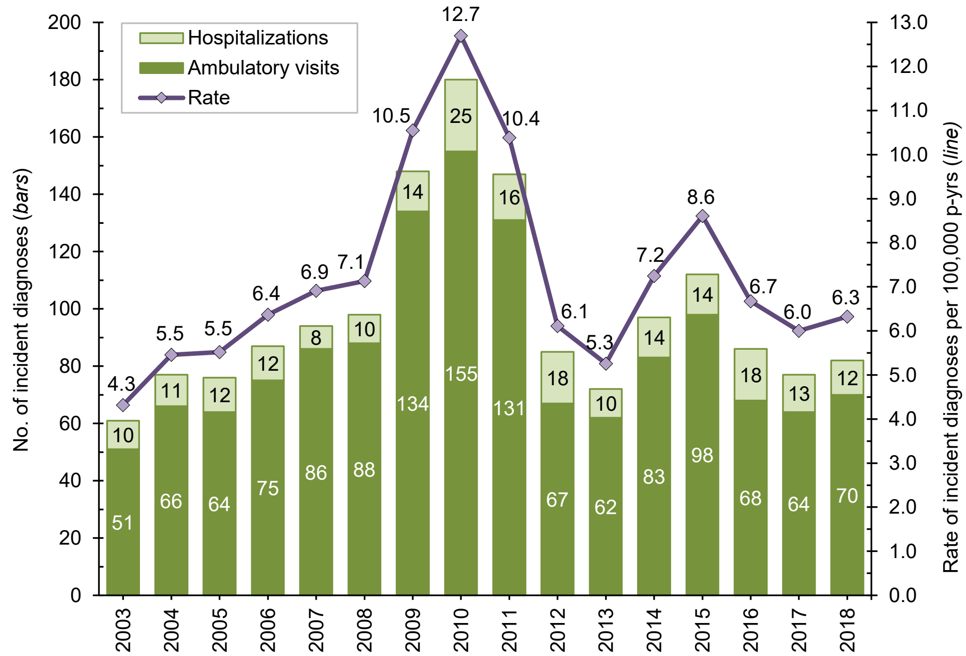
[a]One case per person per year
[b]Number of cases per 100,000 person-years
[c]Infantry/artillery/combat engineering/armor
[d]As self-reported at time of entry into service
No., number

highest incidence rate was among members of the Marine Corps (10.8 per 100,000 p-yrs). In 2018, there were only 11 cases of exertional hyponatremia among recruit trainees, but their incidence rate was 6 times that of officers and more than 7 times that of other enlisted members **(Table 1)**.

During the 16-year surveillance period, females had a slightly higher overall incidence rate of exertional hyponatremia diagnoses than males **(Table 1)**. The overall incidence rate was highest in the Marine Corps (15.2 per 100,000 p-yrs) and lowest in the Navy (4.8 per 100,000 p-yrs). Overall rates during the surveillance period were highest among Asian/Pacific Islander (8.3 per 100,000 p-yrs) and non-Hispanic white service members (8.1 per 100,000 p-yrs) and lowest among non-Hispanic black service members (5.4 per 100,000 p-yrs). Although recruit trainees accounted for less than one-tenth (9.1%) of all exertional hyponatremia cases, their overall crude incidence rate was 5.1 and 3.6 times the rates among other enlisted members and officers, respectively **(Table 1)**. During the 16-year period, 86.3% (n=1,362) of all cases were diagnosed and treated without having to be hospitalized **(data not shown)**.

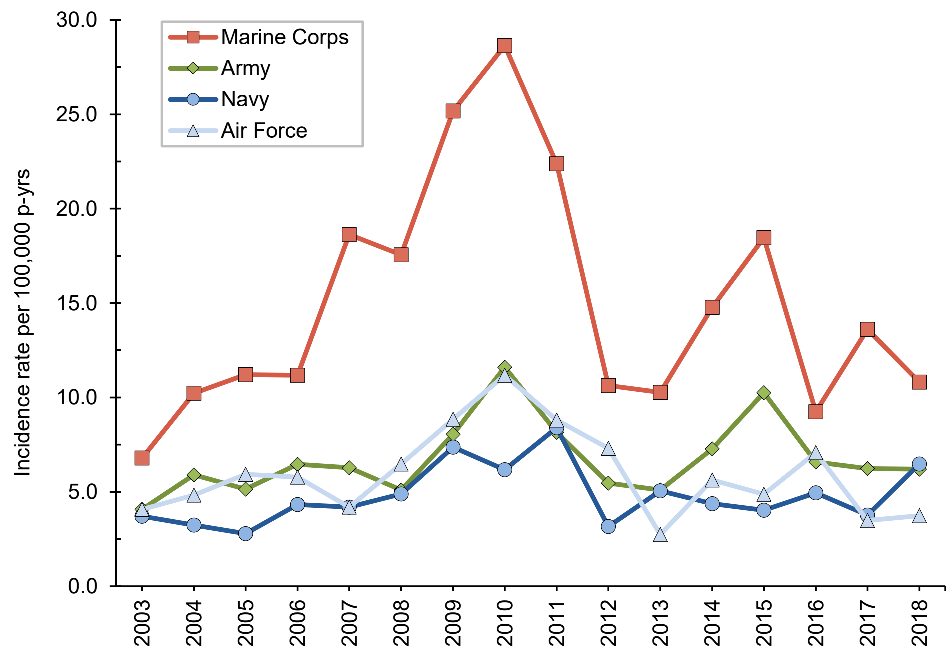
Between 2003 and 2018, crude annual rates of incident exertional hyponatremia diagnoses peaked in 2010 (12.7 per 100,000 p-yrs) and then decreased to 5.3 cases per 100,000 p-yrs in 2013 before increasing in 2014 and 2015. The crude annual incidence rate in 2018 (6.3 per 100,000 p-yrs) represented a decrease of 26.5% from 2015 **(Figure 1)**. During 2003–2018, annual incidence rates of exertional hyponatremia diagnoses were consistently higher among those in the Marine Corps compared to those in the other services, with the overall trend in rates primarily influenced by the trend among Marine Corps members **(Figure 2)**. Between 2017 and 2018, annual incidence rates decreased among Marine Corps members, increased among members of the Navy, and remained relatively stable among members of the Army and the Air Force **(Figure 2)**.

FIGURE 1. Annual incident cases and rates of incident diagnoses of exertional hyponatremia, active component, U.S. Armed Forces, 2003–2018



No., number; p-yrs, person-years

FIGURE 2. Annual incidence rates of exertional hyponatremia, by service, active component, U.S. Armed Forces, 2003–2018



P-yrs, person-years

Exertional hyponatremia by location

During the 16-year surveillance period, exertional hyponatremia cases were diagnosed at the medical treatment facilities of more than 150 U.S. military installations and geographic locations worldwide; however, 14 U.S. installations contributed 20 or more cases each and accounted for 47.6% of the total cases **(Table 2)**. The installation with the most exertional hyponatremia cases overall was the Marine Corps Recruit Depot (MCRD) Parris Island/ Beaufort, SC (n=205).

Exertional hyponatremia in Iraq and Afghanistan

From 2008 through 2018, a total of 18 cases of exertional hyponatremia were diagnosed and treated in Iraq and Afghanistan. Deployed service members who were affected by exertional hyponatremia were

TABLE 2. Incident cases of exertional hyponatremia, by installation (with at least 20 cases during the period), active component, U.S. Armed Forces, 2003–2018

Location of diagnosis	No.	% total
MCRD Parris Island/ Beaufort, SC	205	13.0
Fort Benning, GA	107	6.8
JBSA-Lackland AFB, TX	64	4.1
Fort Bragg, NC	51	3.2
MCB Camp Lejeune/Cherry Point, NC	48	3.0
Walter Reed NMMC, MD[a]	46	2.9
MCB Camp Pendleton, CA	37	2.3
MCB Quantico, VA	36	2.3
NMC San Diego, CA	34	2.2
NMC Portsmouth, VA	32	2.0
Fort Jackson, SC	25	1.6
Fort Shafter, HI	23	1.5
Fort Campbell, KY	22	1.4
Fort Leonard Wood, MO	22	1.4
Other/unknown locations	827	52.4
Total	1,579	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 2 sites prior to the consolidation (November 2011) and the number reported at the consolidated location.

No., number; MCRD, Marine Corps Recruit Depot; JBSA, Joint Base San Antonio; AFB, Air Force Base; MCB, Marine Corps Base; NMC, Naval Medical Center

most frequently male (n=16; 88.9%), non-Hispanic white (n=14; 77.8%), aged 20–24 years (n=8; 44.4%), in the Army (n=13; 72.2%), enlisted (n=15; 83.3%), and in combat-specific (n=7; 38.9%) or communications/intelligence (n=4; 22.2%) occupations **(data not shown)**. During the entire surveillance period, 9 service members were medically evacuated from Iraq or Afghanistan for exertional hyponatremia **(data not shown)**.

EDITORIAL COMMENT

This report documents that after a 2-year period (2014–2015) of elevated numbers and rates of exertional hyponatremia among active component U.S. military members, numbers and rates of diagnoses decreased slightly during 2016–2018. Subgroup-specific patterns of overall incidence rates of exertional hyponatremia (e.g., sex, age, race/ethnicity, service, and military status) were generally similar to those reported in previous *MSMR* updates.[14,15] It is important to note that in *MSMR* analyses prior to April 2018, in-theater cases were included if there was a diagnosis of hypo-osmolality and/or hyponatremia in any diagnostic position. Beginning last year, the same case-defining criteria that were applied to inpatient and outpatient encounters were applied to the in-theater encounters. Therefore, the results of the in-theater analysis are not comparable to those presented in earlier *MSMR* updates.

Several important limitations should be considered when interpreting the results of this analysis. First, there is no 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 hypo-osmolality 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, exertional hyponatremia cases here likely include hyponatremia from both exercise- and non–exercise-related conditions. Consequently, 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. In addition, the accuracy of estimated numbers, rates, trends, and correlates of risk depends on the completeness and accuracy of diagnoses that are documented in standardized records of relevant medical encounters. As a result, an increase in recorded 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 about hyponatremia resulting from excessive water consumption were focused at training—particularly recruit training—installations. In this analysis, rates were relatively high among the youngest, and hence the most junior service members, and the highest numbers of cases tended to be diagnosed at medical facilities that support large recruit training centers (e.g., MCRD Parris Island/Beaufort, SC; Fort Benning, GA; and Joint Base San Antonio–Lackland Air Force Base, TX) and large Army and Marine Corps combat units (e.g., Fort Bragg, NC, and Marine Corps Base Camp Lejeune/Cherry Point, NC).

In response to previous historical cases of exertional hyponatremia in the U.S. military, the guidelines for fluid replacement during military training in hot weather were revised and promulgated in 1998.[16–19] The revised guidelines were designed to protect service members from not only heat injury but also hyponatremia due to excessive water consumption by limiting fluid intake regardless of heat category or work level to no more than 1.5 quarts hourly and 12 quarts daily.[17,18] There were fewer hospitalizations of soldiers for hyponatremia due to excessive water consumption during the year after (vs. the year before) implementation of the new guidelines.[20] In 2003, the revised guidelines were included in the multi-service Technical Medical Bulletin 507, Heat Stress Control and Heat Casualty Management that provides guidance to military and civilian healthcare providers, allied medical personnel, and military leadership.[21] A recent study found that this military fluid intake guidance remains valid for preventing excessive dehydration as well as overhydration and can be used by military health professionals and leadership to adequately maintain a normal level of hydration in service members working in the 5 designated flag conditions (levels of heat/humidity stress) while wearing contemporary uniform configurations (including protective gear/equipment) across a range of metabolic rates.[22]

During endurance events, a "drink-to-thirst" or a programmed fluid intake plan of 400–800 mL per estimated hour of activity has been suggested to limit the risk of exertional hyponatremia, although this rate should be customized to the individual's tolerance and experience.[4,8,18,20] In addition to these guidelines, reducing the availability of fluids may help prevent exertional hyponatremia during endurance events.[23,24] Carrying a maximum fluid load of 1 quart of fluid per estimated hour of activity and encouraging a "drink-to-thirst" approach to hydration may help prevent both severe exertional hyponatremia and dehydration during military training exercises and recreational hikes that exceed 2–3 hours.[4,8,23,24]

Women had relatively high rates of hyponatremia during 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 or load-bearing marches).[9] The finding that the overall incidence of women experiencing exertional hyponatremia was greater than that of men in this analysis is similar to results found among samples of marathon runners in the general population. However, a large study of marathon runners suggested that the apparent sex difference did not remain after adjustment for body mass index and racing times.[25–27]

In many circumstances (e.g., recruit training and Ranger School), military trainees rigorously adhere to standardized training schedules regardless of weather conditions. In hot and humid weather, commanders, supervisors, instructors, and medical support staff must be aware of and enforce guidelines for work–rest cycles and water consumption. The finding in this report that most cases of hyponatremia were treated in outpatient settings suggests that monitoring by supervisors and medical staff identified most cases during the early and less severe manifestations of hyponatremia.

In general, service members and their supervisors must be knowledgeable of the dangers of excessive water consumption as well as the prescribed limits for water intake during prolonged physical activity (e.g., field training exercises, personal fitness training, and recreational activities) in hot, humid weather. Military members (particularly recruit trainees and women) and their supervisors must be vigilant for early signs of heat-related illnesses and intervene immediately and appropriately (but not excessively) in such cases. Finally, the recent validation of the current fluid intake guidance highlights its importance as a resource to leadership in sustaining military readiness.[22]

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Medical Surveillance Monthly Report (MSMR)
Armed Forces Health Surveillance Branch
11800 Tech Road, Suite 220
Silver Spring, MD 20904

MEDICAL SURVEILLANCE MONTHLY REPORT (MSMR), in continuous publication since 1995, is produced by the Armed Forces Health Surveillance Branch (AFHSB). AFHSB is a designated public health authority within the Defense Health Agency. The *MSMR* provides evidence-based estimates of the incidence, distribution, impact, and trends of illness and injuries among U.S. military members and associated populations. Most reports in the *MSMR* are based on summaries of medical administrative data that are routinely provided to the AFHSB and integrated into the Defense Medical Surveillance System for health surveillance purposes.

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ISSN 2158-0111 (print)
ISSN 2152-8217 (online)