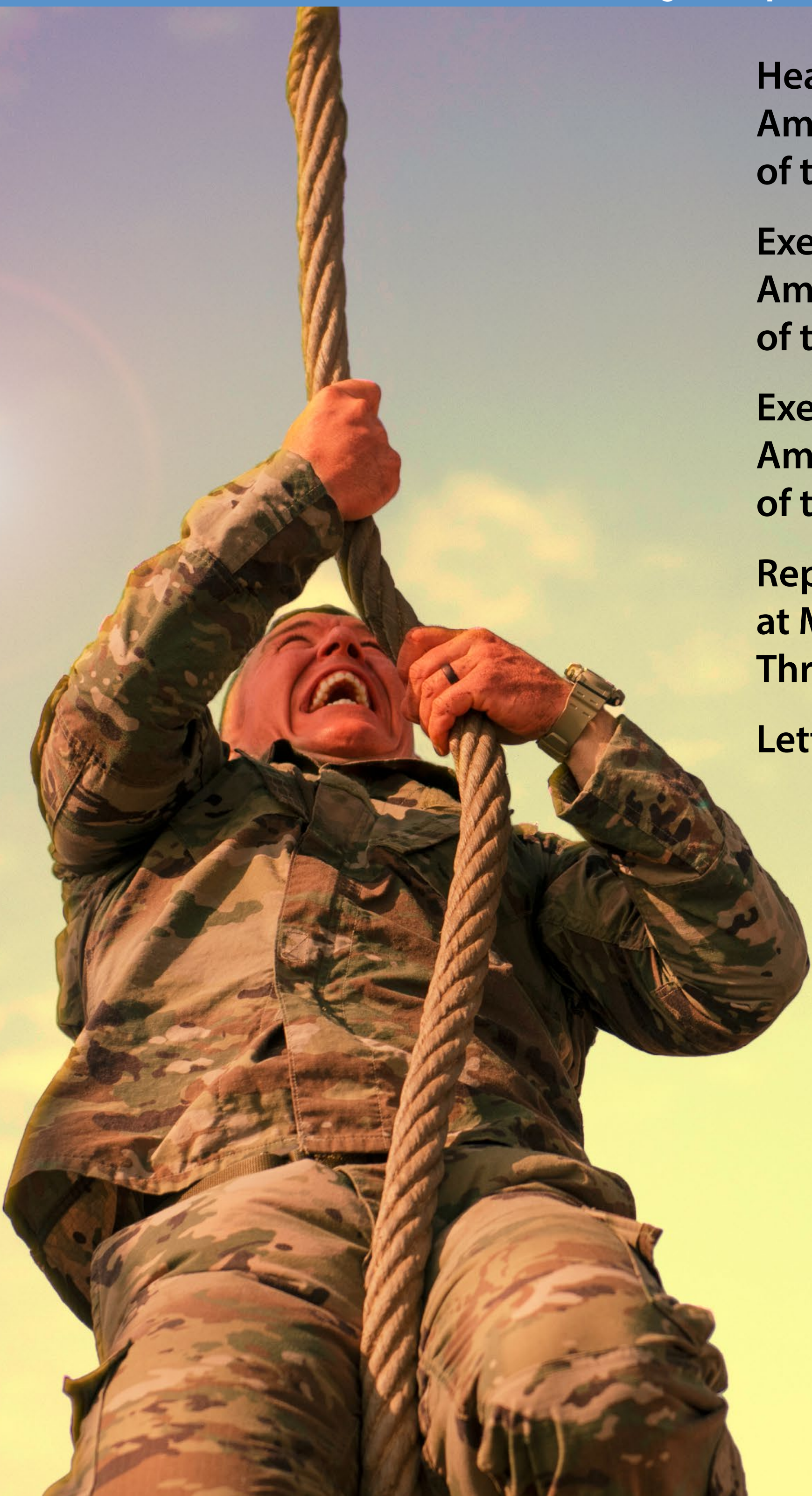
MSMR

Medical Surveillance Monthly Report

June 2025 | Vol. 32 | No. 6



A Publication of the Armed Forces Health Surveillance Division

Medical Surveillance for Military Readiness

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Update

Heat Exhaustion and Heat Stroke Among Active Component Members of the U.S. Armed Forces, 2020–2024

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In 2024, the crude incidence rates of heat stroke and heat exhaustion were 36.4 and 183.9 cases per 100,000 person-years, respectively. After a period of decline in rates of incident heat stroke from 2020 through 2023, during the 2024 surveillance period an increase was observed. When considering only heat exhaustion, incident rates increased each year during the 5-year surveillance period, from 2020 through 2024. In 2024, higher rates of heat stroke were observed among male service members, when compared to their female counterparts, as well as among non-Hispanic White service members compared to service members of other races and ethnicities. Female service members and non-Hispanic Black service members experienced higher rates of heat exhaustion than their male counterparts and service members of other races and ethnicities, respectively. Heat illness rates were also higher among those younger than age 20 years, Marine Corps and Army service members, and recruit trainees. To mitigate the personal and organizational impacts of heat illness, leaders, training cadres, and supporting medical and safety personnel must inform both their subordinate and supported service members of heat illness risks, preventive measures, early signs and symptoms of illness, and appropriate interventions.

What are the new findings?

In 2024, the crude annual incidence rate of heat stroke increased 16.5%, following a 4-year decrease of 10.8% from 2020 to 2023. All services, apart from the Space Force and Coast Guard, had a higher rate of heat stroke in 2024 than in 2023. The crude annual incidence rate of heat exhaustion increased 52.3% from 2020 to 2024, with incremental increases annually. Increased rates of heat exhaustion in 2024 from 2023 were observed in the Army, Marine Corps, and Coast Guard.

What is the impact on readiness and force health protection?

The most serious types of heat illnesses, heat exhaustion and heat stroke, are occupational hazards associated with many of the military's training and operational environments, posing potential risks for force health protection. Heat exhaustion and heat stroke can typically be prevented by accurate situational awareness, appropriate risk management strategies, and effective countermeasures. Units that fail to implement heat illness mitigation measures risk impeding or interrupting training programs, resulting in otherwise preventable reductions in operational tempo or critical mission failure due to lost personnel and resources.

Military personnel in the U.S. Armed Forces are required to train and operate at high physical intensity in environments with potentially extreme conditions to maintain force readiness and perform mission essential activities. One occupational hazard of intense physical exertion combined, in some cases, with hot temperatures and humid environments is the occurrence of heat illness. Heat illness refers to a group of disorders that result from a disruption of thermoregulation due to heat stress caused by high energy expenditure (i.e., metabolic heat production), environmental heat exposure, or a combination of both factors.[1-4]

While temperature and humidity are well recognized environmental risk factors for heat illness, there are individual, organizational, and occupational risk factors that influence heat illness occurrence. Individual factors include lack of acclimatization, physical fitness levels, pre-existing or recent viral illness, body composition, and motivation to excel.[5-6] Organizational factors include type of activity, training intensity and duration, and training schedules. These risk factors do not work independently of each other, there is literature to suggest that risk factors interact to increase risk of heat illness, making it essential that military leaders and service members recognize the full spectrum of factors at play in a training or operational environment.[7] For example, metabolic heat production increases during prolonged engagement in strenuous physical activity, and additional exposure to environmental heat stress elevates core and skin temperatures.[2,3,8]

While identifying high-risk service members is critical in preventing heat illness and reducing morbidity due to heat illnesses, heat illness mitigation strategies can be layered using a risk management model.[9] For achieving the goal of hazard reduction, progressive training, heat acclimatization, and ensuring proper hydration, electrolyte replacement, and nutrition prior to training are strategies that can prepare service members for training and operating in high heat environments.[3,10] Risk mitigation strategies that can be applied during training events include implementing work and rest guidelines, modifying clothing and uniform standards, adopting self- or group-pacing during high-risk events (e.g., ruck marches), modifying schedules or activities, and providing cooling measures (e.g., arm immersion cooling or microclimate cooling).[9-11] Further, early detection reduces morbidity and severity of heat illness and can be achieved by educating service members and leadership on the signs and symptoms of heat illness, incorporating physiological monitoring, managing outliers during training (i.e., establishing minimum or maximum pacing), and removing individuals from high-risk events. Finally, effective management of heat casualties includes applying proper cooling techniques (e.g., cold water immersion, iced sheets).[6,9,11]

Heat illness occurs within a continuum of severity, from less severe (e.g., heat cramps, rash, edema, syncope), to heat exhaustion, followed by potentially life-threatening heat stroke. Heat exhaustion and heat stroke are reportable medical events (RMEs) in the Military Health System (MHS). All heat casualties that require medical intervention or result in change of duty status must be reported.[12] During or immediately following a period of physical exertion or heat exposure, specific signs and symptoms that characterize heat illnesses allow initial recognition of their occurrence in the field, and subsequent identification or diagnosis of a heat illness that should be reported.

Common signs and symptoms of heat exhaustion include weakness, muscle cramps, headache, dizziness, nausea or vomiting, tachycardia, and short-term physical collapse or debilitation. Heat exhaustion is often characterized by evidence of elevated core body temperature (not greater than 104 °F, 40 °C) with no significant central nervous system dysfunction. If any central nervous system dysfunction develops (e.g., dizziness, confusion, headache), it should be mild and rapidly resolve with rest and cooling measures, otherwise the individual may be experiencing heat stroke.[5,8,13-14]

Heat stroke is a debilitating and potentially life-threatening condition most frequently characterized by evidence of severe hyperthermia (greater than or equal to 104 °F, 40 °C) and central nervous system dysfunction (e.g., change in mental status, delirium, stupor, loss of consciousness, coma).[5,8,13,15] Onset of heat stroke should prompt aggressive intervention featuring rapid cooling (e.g., iced sheets). The literature on heat stroke management indicates consensus on prioritizing cooling over transport for further medical attention.[9,15-17] Cooling is prioritized because, clinically, severity of end-organ damage and increased possibility of mortality are directly related to the degree and duration of hyperthermia.[8,11,17] End-organ damage is most frequently observed in the liver, kidneys, cardiac, and skeletal muscle.[8,15-16,18]

Ongoing surveillance of heat illnesses is necessary to determine if prevention guidelines and countermeasures are working, in addition to identifying high-risk groups and activities that may lead to heat illness. Since 2001 *MSMR* has published regular updates on the incidence of heat illness among U.S. active component service members (ACSMs). This update presents summaries of heat stroke and heat exhaustion case counts, incidence rates, and locations from 2020 through 2024.

Methods

The surveillance population for this analysis includes all individuals who served in the active component of the Army, Navy, Marine Corps, Air Force, Space Force, or Coast Guard at any time during the surveillance period of January 1, 2020 through December 31, 2024. Space Force data are only complete for 2023 and 2024.

All data used to determine incident heat illness diagnoses were derived from 4 sources: MHS Management, Analysis and Reporting Tool (M2); Defense Medical Surveillance System (DMSS); Disease Reporting System internet (DRSi); and Theater Medical Data Store (TMDS). Heat illness cases were identified using specific diagnostic codes from the ambulatory care encounters and hospitalizations of ACSMs in fixed military and civilian (if reimbursed through the MHS) hospitals and clinics worldwide. In addition to medical encounter data, heat illness medical event reports were identified in DRSi, including information on hospitalization status (i.e., yes or no). If a heat illness was reported in DRSi, but not found in the medical record, the case was still counted. For example, an individual could be treated in the field by a medic for a mild or non-life-threatening heat illness without a recorded medical encounter, but the case is deemed a reportable heat exhaustion because of symptoms observed in the field.

In this update, a case of heat illness was defined as an individual with 1) a hospitalization or outpatient medical encounter record or outpatient medical encounter record 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 RME record of heat exhaustion or heat stroke[19]; asterisks denote that all subsequent digits or characters noted in that diagnostic code were included in the identification of ICD-10 codes (e.g., T67.3XXA).

An individual was considered a case of heat illness only once per calendar year. If a service member had diagnoses for both heat stroke and heat exhaustion during a given year, the more severe diagnosis (i.e., heat stroke) was selected. If a service member had inpatient and outpatient encounter for heat stroke or heat exhaustion, the inpatient encounter was prioritized over the outpatient visit, when identifying hospitalized cases. Within a calendar year, if an individual had a diagnostic code that denoted a subsequent encounter (i.e., ICD-10 seventh digit 'D') or an encounter for sequelae (i.e., ICD-10 seventh digit 'S'), but had no diagnostic codes indicating an initial visit (i.e., ICD-10 seventh digit 'A'), the case was removed to avoid over-estimating heat illness cases by including those receiving follow-up care.

For health surveillance purposes, recruit trainees were identified as ACSMs assigned to service-specific training locations and basic training periods, using an algorithm based on age, rank, and time in service. Recruit trainees were considered a separate enlisted service member category in heat illness summaries by military grade.

In summaries of heat illness by location, the Defense Medical Information System Identifier (DMIS ID) was utilized to determine installation or geographic location of diagnosis and medical treatment.

In-theater diagnoses of heat illness, within the U.S. Central Command (CENTCOM) area of responsibility (AOR), were identified from medical records of deployed service members whose health care encounters were documented in TMDS. Those encounters were analyzed separately, and the same case-defining criteria and incidence rules described previously were applied.

Incidence rates were calculated as incident cases of heat illness per 100,000 ACSM person-years (p-yrs). Percent change in incidence was calculated using unrounded rates. Because reporting of heat exhaustion and heat stroke cases is required, the proportion of outpatient and inpatient cases with a report in DRSi was also calculated.[12]

Results

In 2024, 471 cases of heat stroke were reported throughout the MHS, resulting in a crude incidence rate of 36.4 cases per 100,000 p-yrs **(Table 1)**. Subgroup-specific incidence rates of heat stroke were highest among men, those younger than age 20 years, non-Hispanic White service members, Marine Corps and Army personnel, recruit trainees, as well as those in combat-specific occupations. The incidence rate of heat stroke among recruit trainees was 3.3 and 3.5 times higher than other enlisted service members and officers, respectively.

After decreasing for 4 years, in 2024 the crude annual incidence of heat stroke increased 16.5% **(Figure 1)**. Incidence rates of heat stroke increased in 2024 among service members in the Air Force (95.3%), Marine Corps (25.6%), Navy (17.8%), and Army (6.4%) **(Table 2)**. Meanwhile, the proportion of heat stroke cases that were hospitalized decreased, to 35.5% in 2024, from 39.7% in 2023 **(Figure 1)**. Of all inpatient heat stroke cases from 2020 through 2024, 74.7% were reported to DRSi, while over half (57.9%) of outpatient heat stroke cases had a medical event report in DRSi.

TABLE 1. Incident Cases[a] and Incidence Rates[b] of Heat Illness, Active Component, U.S. Armed Forces, 2024

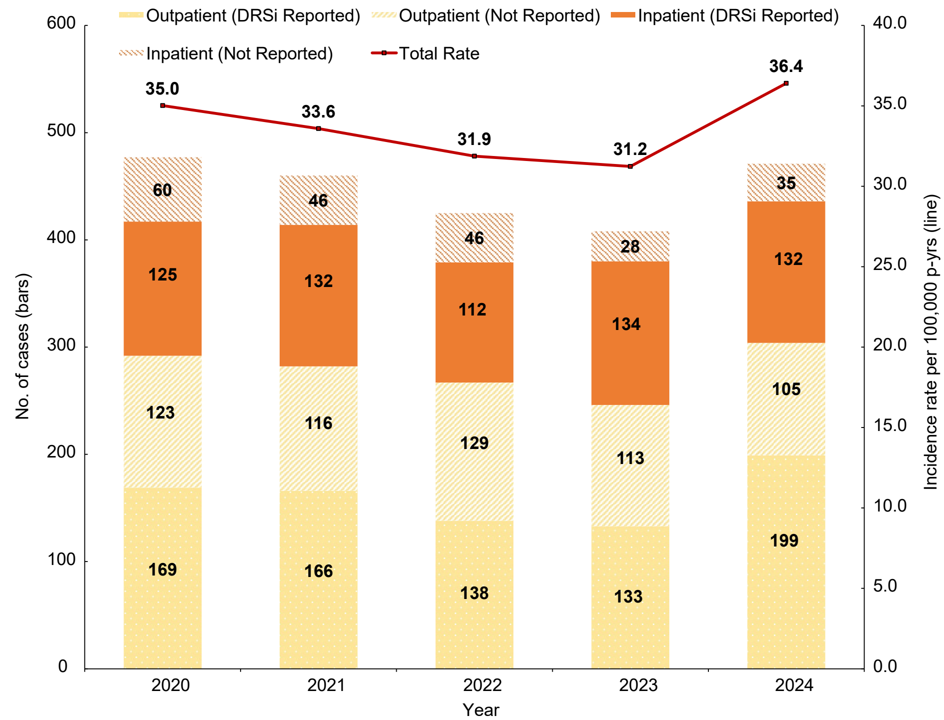
	Heat Stroke		Heat Exhaustion		Total Heat Illness Diagnoses	
	No.	Rate[b]	No.	Rate[b]	No.	Rate[b]
Total	471	36.4	2,380	183.9	2,851	220.3
Sex						
Male	414	38.9	1,885	177.2	2,299	216.1
Female	57	24.8	495	215.1	552	239.8
Age group, y						
<20	86	104.9	624	761.2	710	866.1
20–24	196	50.6	1,020	263.1	1,216	313.7
25–29	130	42.7	406	133.4	536	176.1
30–34	37	17.1	182	84.2	219	101.3
35–39	15	9.0	97	57.9	112	66.8
40+	7	5.1	51	37.5	58	42.6
Race and ethnicity						
White, non-Hispanic	305	45.8	1,454	218.5	1,759	264.3
Black, non-Hispanic	80	38.1	495	235.8	575	273.9
Hispanic	24	9.3	141	54.6	165	63.8
Other/unknown[c]	62	38.8	290	181.3	352	220.0
Service branch						
Army	246	55.8	1,207	273.9	1,453	329.7
Navy	42	13.0	201	62.0	243	75.0
Air Force	39	12.5	297	95.3	336	107.9
Marine Corps	143	84.7	655	388.2	798	472.9
Space Force	0	0.0	4	43.1	4	43.1
Coast Guard	1	2.5	16	40.5	17	43.0
Military status						
Recruit trainee	27	116.6	553	2,388.9	580	2,505.5
Enlisted	363	35.3	1,643	159.8	2,006	195.1
Officer	81	33.4	184	75.8	265	109.2
Military occupation						
Combat-specific[d]	156	96.5	485	300.1	641	296.6
Motor transport	8	19.0	66	156.6	74	175.6
Pilot/air crew	7	15.5	13	28.9	20	44.4
Repair/engineering	34	9.4	148	41.1	182	50.6
Communications/intelligence	10	3.6	30	10.8	40	14.4
Health care	24	22.8	96	91.1	120	113.9
Other/unknown	232	76.8	1,542	510.8	1,774	587.6

Abbreviations: No., number; y, years.
[a]One case per person per calendar year.
[b]Rate per 100,000 person-years.
[c]Includes those of American Indian/Alaskan Native, Asian, Native Hawaiian/Pacific Islander, and unknown race or ethnicity.
[d]Infantry/artillery/combat engineering/armor.

The 2,380 cases of heat exhaustion in 2024 correspond to a crude incidence rate of 183.9 cases per 100,000 p-yrs **(Table 1)**. As with heat stroke, higher rates of heat exhaustion were noted for service members younger than age 20 years, Marine Corps and Army personnel, and recruit trainees. Unlike heat stroke, however, the rate of heat exhaustion was higher among women (21.4% higher compared to men) and non-Hispanic Black service members (7.9% higher compared to non-Hispanic White service members). The incidence rate of heat exhaustion among recruit trainees was 14.9 and 31.5 times higher than other enlisted service members and officers, respectively.

The crude annual incidence rate of heat exhaustion increased each year of the 5-year surveillance period **(Figure 2)**, with a 52.3% increase from 2020 through 2024—including a 6.3% increase from 2023 to 2024. Service-specific increases in incidence rates of heat exhaustion were observed in 2024 among Marine Corps (34.3%) and Army personnel (3.1%) from the rates observed in 2023 **(Table 2)**.

FIGURE 1. Incident Cases[a] and Incidence Rate of Heat Stroke, by Encounter Type and Year of Diagnosis, Active Component, U.S. Armed Forces, 2020–2024



Abbreviations: No., number; p-yrs, person-years.
[a] Diagnosis codes were prioritized by severity and record source: heat stroke > heat exhaustion, hospitalizations > ambulatory visits; Not Reported indicates cases not reported to DRSi.

TABLE 2. Annual Incident Cases[a] and Incidence Rates[b] of Heat Illness, by Service, Active Component, U.S. Armed Forces, 2020–2024

	Army		Navy		Air Force		Marine Corps		Space Force		Coast Guard	
	No.	Rate[b]	No.	Rate[b]	No.	Rate[b]	No.	Rate[b]	No.	Rate[b]	No.	Rate[b]
Heat exhaustion												
2020	899	189.2	135	40.1	130	39.6	473	259.8	—	—	9	22.2
2021	1,034	216.0	147	43.0	183	55.6	496	276.5	—	—	5	12.4
2022	1,036	224.9	190	56.2	237	73.8	555	319.1	—	—	19	47.9
2023	1,190	265.5	207	63.3	363	115.3	488	288.9	7	81.9	6	15.5
2024	1,207	273.9	201	62.0	297	95.3	655	388.2	4	43.1	16	40.5
Heat stroke												
2020	284	59.8	24	7.1	17	5.2	152	83.5	—	—	0	0.0
2021	297	62.1	25	7.3	27	8.2	111	61.9	—	—	0	0.0
2022	226	49.1	31	9.2	32	10.0	135	77.6	—	—	1	2.5
2023	235	52.4	36	11.0	20	6.4	114	67.5	0	0.0	3	7.7
2024	246	55.8	42	13.0	39	12.5	143	84.7	0	0.0	1	2.5
Total heat illness diagnoses												
2020	1,183	249.0	159	47.3	147	44.7	625	343.3	—	—	9	22.2
2021	1,331	278.1	172	50.3	210	63.8	607	338.4	—	—	5	12.4
2022	1,262	274.0	221	65.4	269	83.7	690	396.7	—	—	20	50.4
2023	1,425	318.0	243	74.3	383	121.7	602	356.4	7	81.9	9	23.2
2024	1,453	329.7	243	75.0	336	107.9	798	472.9	4	43.1	17	43.0

Abbreviations: No., number; y, years.
[a] One case per person per calendar year.
[b] Rate per 100,000 person-years.

The proportion of heat exhaustion cases that were hospitalized in the U.S. Armed Forces decreased, however, from 2023 (5.9%) to 2024 (4.6%) **(Figure 2)**.

Over three-quarters (76.6%) of inpatient heat exhaustion cases were reported in DRSi from 2020 to 2024, while only 37.6% of outpatient heat exhaustion cases had a medical event report in DRSi.

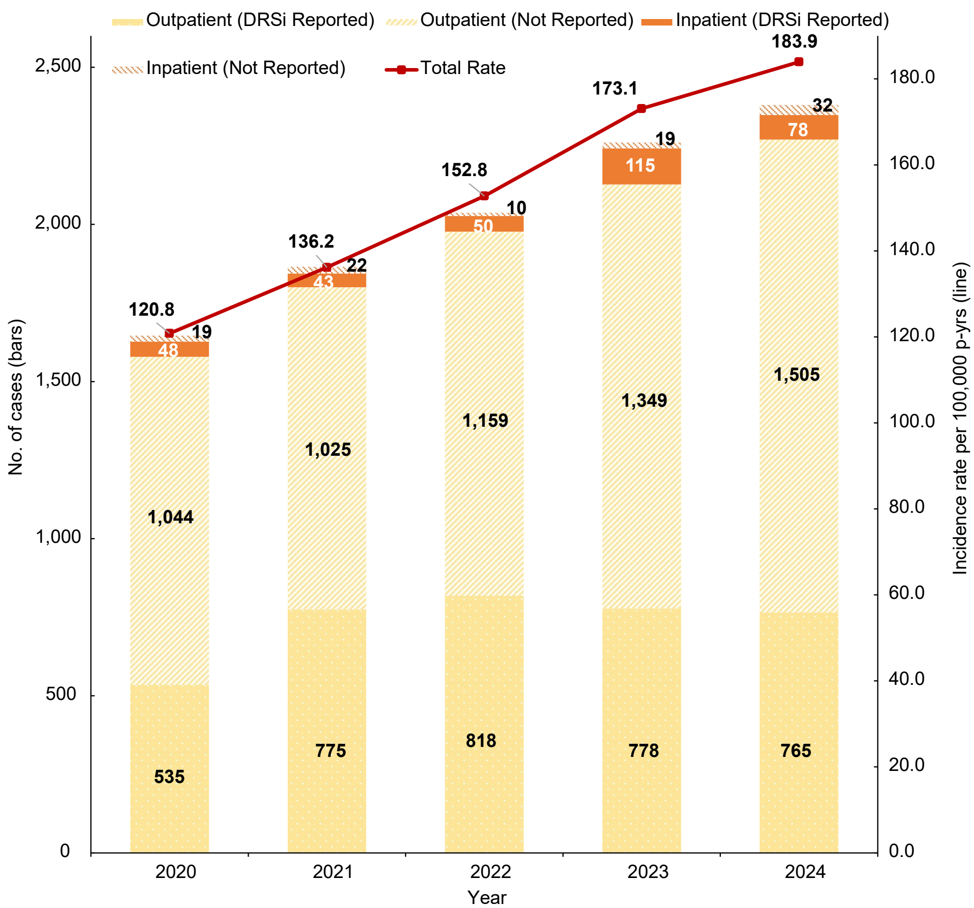
Heat illnesses by location

During the 5-year surveillance period, 12,430 heat illness cases were diagnosed at more than 300 military installations and geographic areas worldwide **(Table 3)**. Only 6.9% of those heat illness cases occurred outside the U.S., including 344 in Okinawa, Japan. From 2020 to 2024, 22 locations reported at least 100 cases of heat illness, and those 22 locations accounted for over three-quarters (77.4%) of all active component cases. Three Army installations (Fort Benning, GA; Fort Bragg, NC; Fort Campbell, KY), 2 Marine Corps bases (MCB Camp Lejeune/Cherry Point, NC, MCRD Parris Island/Beaufort, SC), and 1 Joint Base (JB San Antonio, TX) accounted for 44% of the total heat illnesses during the surveillance period. Of the 22 locations with at least 100 cases of heat illness, 15 are in the southern U.S.

Heat illnesses in CENTCOM AOR

During the 5-year surveillance period, 269 cases of heat illness were reported in the CENTCOM AOR **(Figure 3)**. Of those 269 cases of heat illness, 7.4% (n=20) were heat stroke. Cases of heat illness occurred most frequently among deployed service members who were male (n=188, 69.9%), 20-24 years old (n=133, 49.4%), and in the Navy (n=119, 44.2%) or Air Force (n=75, 27.9%) (data not shown).

FIGURE 2. Incident Cases[a] and Incidence Rates of Heat Exhaustion, by Encounter Type and Year of Diagnosis, Active Component, U.S. Armed Forces, 2020–2024



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

[a] Diagnosis codes were prioritized by severity and record source: heat stroke > heat exhaustion; hospitalizations > ambulatory visits; Reported indicates case was reported to DRSi; Not Reported indicates case was not reported to DRSi.

Discussion

During the 5-year surveillance period, the rate of heat stroke decreased annually from 2020 through 2023, but then increased in 2024. The rate of heat exhaustion increased steadily from 2020 to 2024. Between 2023 and 2024, the rate of heat stroke increased 16.5%, and the rate of heat exhaustion increased 6.3%. For both heat stroke and heat exhaustion cases, however, the percentage of hospitalized cases declined from 2023 to 2024. While the reason for the increase in heat illness cases in 2024 is unknown, the decrease in hospitalized cases is indicative of fewer severe cases of heat illness that required higher level inpatient medical care. It is possible that current heat illness prevention guideline emphasis on education about the signs, symptoms, and management of heat casualties leads to earlier and more frequent recognition of what constitutes a heat illness while also preventing more severe heat illness.[3,10,20-21]

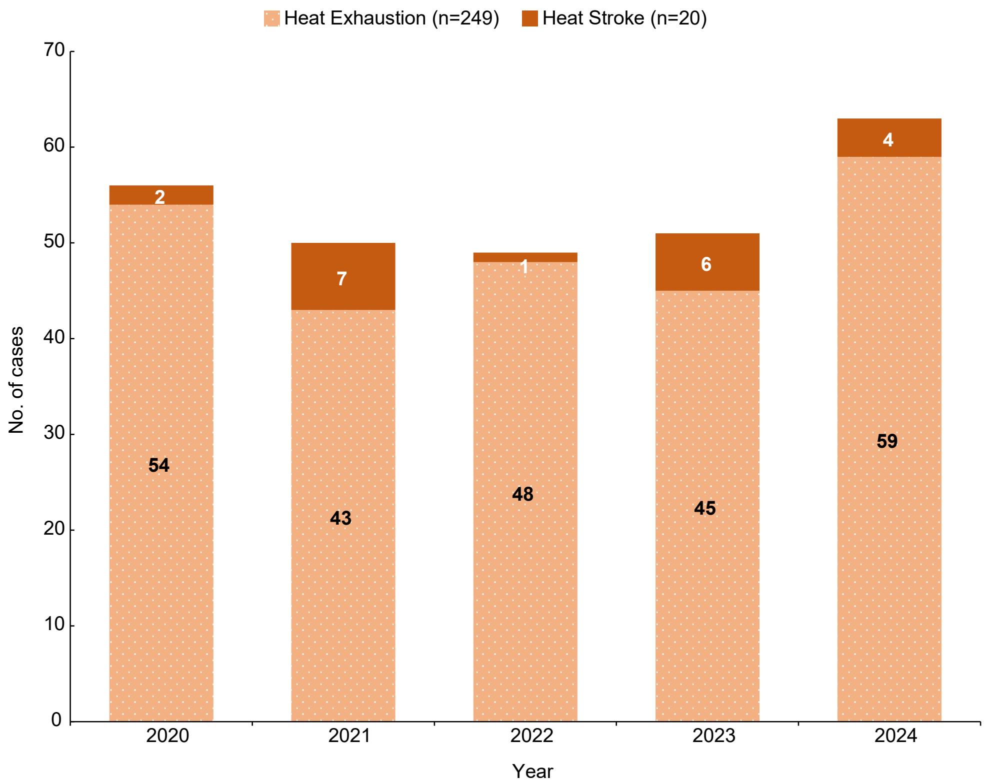
There are limitations to this update that should be considered when interpreting its findings. Although heat illnesses were summarized by the location of diagnosis or report, medical care may not occur at the same location (i.e., installation) as the heat illness event, particularly if the case required a level of care not available locally. To account for locations with medical care redundancy, some installations were combined (e.g., MCB Camp Lejeune/Cherry Point, NC in **Table 3**); this merging of locations was most prevalent with Marine Corps and Navy locations. In addition, the personnel files from the Defense Manpower Data Center that were utilized to calculate population estimates for the active component as well as the demographic data

TABLE 3. Heat Injury Events[a] by Location of Diagnosis or Report with at Least 100 Cases During the Period, Active Component, U.S. Armed Forces, 2020–2024

Location of Diagnosis	No.	% Total
Fort Benning, GA	1,839	14.8
MCB Camp Lejeune/ Cherry Point, NC	894	7.2
Fort Bragg, NC	833	6.7
JB San Antonio, TX	656	5.3
MCRD Parris Island/ Beaufort, SC	642	5.2
Fort Campbell, KY	606	4.9
Fort Johnson, LA	475	3.8
MCRD San Diego/ NB San Diego	473	3.8
Fort Cavazos, TX	425	3.4
Okinawa, Japan	344	2.8
MCB Camp Pendleton, CA	333	2.7
MCB Quantico, VA	330	2.7
Fort Jackson, SC	318	2.6
Fort Sill, OK	287	2.3
Fort Irwin, CA	197	1.6
Twentynine Palms, CA	183	1.5
Fort Shafter, HI	159	1.2
Fort Stewart, GA	155	1.2
Fort Leonard Wood, MO	139	1.1
Fort Bliss, TX	128	1.0
NAS Pensacola, FL	105	0.8
NSA Annapolis, MD	103	0.8
Outside U.S.[b]	510	4.1
All other locations	2,296	18.5
Total	12,430	100

Abbreviations: No., number; MCB, Marine Corps Base; MCRD, Marine Corps Recruit Depot; NAS, Naval Air Station; NB, Naval Base; NSA, Naval Support Activity; JB, Joint Base.
[a]One heat illness per person per year.
[b]Excluding Okinawa, Japan.
Note: Initial entry recruit training locations include Fort Jackson, Fort Leonard Wood, Fort Benning, Fort Sill, MCRD Parris Island/Beaufort, MCRD San Diego/NB San Diego, and JB San Antonio. Fort Johnson is the Joint Readiness Training Center (JRTC) and Fort Irwin is the National Training Center (NTC).

FIGURE 3. Incident Cases of Heat Illnesses in CENTCOM Area of Responsibility, Active Component, U.S. Armed Forces, 2020–2024



Abbreviations: n, number; No., number.

presented in **Table 1** were unavailable for October through December 2024; the duty statuses of all service members in September 2024 were assumed to be their duty statuses through the end of the calendar year. It is likely that some individuals in the U.S. Armed Forces both joined and left service during those months, and those movements are unaccounted for in the population estimates. Likewise, it is possible some time-varying demographics (e.g., rank) changed for individuals from October through December 2024 compared to September, and those shifts in categories are unaccounted for. In all instances, however, the effect on the rates shown throughout the report should be minimal due to the large population size.

Further, the method used to identify recruit trainees likely resulted in some misclassification of recruit training status. The algorithm did not account for the additional training time in the Army's One Status Unit Training beyond the traditional basic combat training period and does not account for service members who are recycled through training, likely leading to an under-estimation of the incident cases and incidence rates of heat illnesses among recruit trainees. Finally, there was likely incomplete capture of heat illnesses treated in the field during training and deployments, rather than at a fixed military hospital or clinic; this may be particularly true for heat exhaustion cases when symptoms rapidly resolve after a period of rest.

Maintaining regular heat illness surveillance helps identify the magnitude of the impact these conditions have on service member health, training, and force readiness. At the command and unit level, emphasis on evidence-based prevention, mitigation and risk management, with continued education on the signs, symptoms, and early field interventions for heat illness, are crucial steps in reducing the impact of heat illness morbidity on the force. To ensure protection throughout the force, DOD standards, policies, or procedures should determine the prevention, mitigation, and management of heat illnesses.

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Update

Exertional Rhabdomyolysis Among Active Component Members of the U.S. Armed Forces, 2020–2024

Exertional rhabdomyolysis is a pathologic muscle breakdown associated with strenuous physical activity. A largely preventable condition, it persists as an occupational hazard of military training and operations, especially in high heat environments among individuals pushing their endurance limits. A total of 464 cases of exertional rhabdomyolysis were identified in 2024, corresponding to a crude incidence rate of 35.9 cases per 100,000 person-years, and is the lowest case count recorded during the 2020-2024 period of surveillance. The 2024 case numbers demonstrated a 9.6% reduction from the peak rate in 2023, and the proportion of 39.7% hospitalized in 2024 represented a 4.0% decrease from 2023. In 2024, all services, excepting the Navy, showed declines in incidence rates, ranging from 2.0% in the Coast Guard to 29.1% in the Air Force, compared to 2023. Consistent with prior reports, subgroup-specific crude rates in 2024 were highest among men, those less than 20 years old, non-Hispanic Black service members, Marine Corps or Army members, and those in combat-specific or 'other' military occupations. Recruit trainees continued to experience the highest rates of exertional rhabdomyolysis in 2024, with a rate more than 13 times greater than officers and enlisted members.

What are the new findings?

During the 2020-2024 surveillance period, 2024 evinced the lowest incidence rate of exertional rhabdomyolysis, nearly 10% lower than the peak observed in 2023. The Air Force showed the largest reduction, with incidence rates decreasing approximately 30% from the previous year.

What is the impact on readiness and force health protection?

Exertional rhabdomyolysis is a serious threat to military members than can limit their service effectiveness and potentially predispose them to serious injury. Risk of developing exertional rhabdomyolysis can be reduced with prompt recognition of symptoms by commanders, informed by awareness of environmental conditions, cognizance of troop fitness levels, emphasis on graded preconditioning prior to more strenuous training, and adherence to recommended work and rest ratios with appropriate hydration schedules, especially in hot, humid weather.

Initiation of a high-intensity physical activity at unaccustomed intensity or duration, particularly under heat stress, increases the risk of exertional rhabdomyolysis.[1] A potentially serious condition, exertional rhabdomyolysis requires vigilance for early diagnosis and aggressive treatment to prevent serious consequences. Rhabdomyolysis is characterized by the breakdown of skeletal muscle cells and leakage of intracellular contents (e.g., myoglobin, sarcoplasmic proteins, electrolytes) into the extracellular fluid and the circulatory system. Myoglobin is toxic to the tubular cells of the kidney and can lead to renal failure.

Rhabdomyolysis severity ranges from asymptomatic or mild elevation of serum muscle enzyme levels to life-threatening emergencies, such as electrolyte imbalances, acute kidney failure, disseminated intravascular coagulation, compartment syndrome, cardiac arrhythmia, or liver dysfunction.[1-4] The characteristic triad of rhabdomyolysis symptoms are muscle pain, weakness, and red- to brown-colored urine, due to high levels of myoglobin, although over half of patients do not have all of these specific symptoms.[5]

The standard diagnostic criteria for exertional rhabdomyolysis are elevated serum creatine phosphokinase (CPK) levels, indicating myonecrosis, usually defined as a CPK level of at least 5 times the upper limit of normal, following recent exercise.[2,3,6]

The condition is most commonly identified among new recruits at recruit training and combat installations, during the first 90 days of basic training,[7,8] but it can be observed in athletes accustomed to intense training,[9] particularly when they extend themselves to the maximal limits of their physical endurance.[10] History of heat illness or prior heat stroke have also been described as significant risk factors for recruits who sustained rhabdomyolysis,[8,11] revealing the potential for co-morbid conditions.

MSMR annually summarizes the numbers, rates, trends, risk factors, and locations of exertional heat injury occurrences including exertional rhabdomyolysis. This report includes updated surveillance data from 2020 through 2024. Additional information about the definition, causes, and prevention of exertional rhabdomyolysis can be found in previous issues of *MSMR*.[7]

Methods

The surveillance period ranged from January 2020 through December 2024 and included all individuals who served in the active component of the Army, Navy, Air Force, Marine Corps, Space Force, or Coast Guard. Due to small numbers, Space Force members were included in the Air Force population. 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) hospitals and clinics worldwide.

A case of exertional rhabdomyolysis was defined as an individual with ICD-9 and ICD-10 diagnostic codes in any position indicating a hospitalization or outpatient medical encounter with either "rhabdomyolysis" or "myoglobinuria," plus a diagnosis in any position of one of the following: "volume depletion (dehydration)," "effects of heat and light," "effects of thirst (deprivation of water)," "exhaustion due to exposure," or "exhaustion due to excessive exertion (overexertion)" **(Table 1)**.[12] Each individual could be considered an incident case of exertional rhabdomyolysis only once per calendar year.

Cases of rhabdomyolysis associated with trauma, intoxications, and adverse drug reactions were excluded.[11] For health surveillance purposes, recruit trainees were identified as active component members assigned to service-specific training locations during coincident, service-specific basic training periods. Recruit trainees were considered a separate enlisted service member category in exertional rhabdomyolysis summaries by military grade.

Results

In 2024, a total of 464 cases of rhabdomyolysis were identified that were likely associated with physical exertion or heat stress (i.e., exertional rhabdomyolysis)—which represents the lowest annual recorded number of cases during the 2020-2024 surveillance period **(Table 2, Figure 1)**. The crude incidence rate per 100,000 person-years (p-yrs) declined to 35.9, a 9.6% reduction from the peak rate of 39.7 observed in 2023 **(Figure 1)**. Incidence rates remained relatively stable, ranging from 38.0 to 38.4 cases per 100,000 p-yrs during the first 3 years of the surveillance period. The percent hospitalized was 39.7% (n=184), a 4.0% decrease from the corresponding percentage in 2023. Hospitalization proportions were lowest in 2020, at 32.8%, with an average of 38.8% over the 5-year period **(Figure 1)**.

Consistent with prior annual reports, crude incidence rates remained highest among men, those younger than age 20 years, non-Hispanic Black service members, Marine Corps or Army members, and those in 'other' and combat-specific occupations **(Table 2)**. Recruit trainees continued to have the highest rates of exertional rhabdomyolysis in 2024, at a rate of over 13 times greater than officers and enlisted members.

By service, the highest incidence rates of exertional rhabdomyolysis were observed in the Marine Corps and the Army, at 84.7 (n=143) and 53.8 (n=237) cases per 100,000 p-yrs, respectively. Rates in the Air Force (n=38), the Navy (n=41) and the Coast Guard (n=5) were similar, ranging from 11.8 to 12.7 cases per 100,000 p-yrs. With the exception of the Navy, all service branches showed declines in incidence in 2024, ranging from as little as 2.0% in the Coast Guard to as much as 29.1% in the Air Force, compared to 2023 **(Figure 2)**. The incidence rate of exertional rhabdomyolysis in the Navy was lowest in 2023 at 10.7 cases per 100,000 p-yrs but increased by 18.3% to 12.7 cases per 100,000 p-yrs in 2024. No cases were identified among Space Force members. When stratified by race and ethnicity, incidence rates declined the most among individuals of the other or unknown category, from 34.2 per 100,000 p-yrs in 2023 to 25.6 cases per 100,000 p-yrs in 2024, a 25.1% reduction (data not shown). The rate decreased by 16.7% among non-Hispanic White service members (from 36.0 cases per 100,000 p-yrs in 2023 to 30.0 cases per 100,000 p-yrs in 2024). Rates remained relatively stable among non-Hispanic Black and Hispanic individuals.

During 2020-2024, approximately three-quarters (75.4%) of cases occurred during the warmer months (April through September) **(Figure 3)**.

During the 5-year surveillance period, 22 installations diagnosed at least 20 cases each; when combined, these installations diagnosed 67.6% of all cases **(Table 3)**. Of those 22 installations, 6 support recruit or basic combat training centers: Marine Corps Recruit Depot (MCRD) Parris Island/Beaufort, SC; Fort Benning, GA; Joint Base San Antonio-Lackland, TX; Fort Leonard Wood, MO; MCRD San Diego, CA;

TABLE 1. ICD-9 and ICD-10 Diagnostic Codes Used to Define a Case of Exertional Rhabdomyolysis

Primary condition	ICD-9	ICD-10
Rhabdomyolysis	728.88	M62.82
Myoglobinuria	791.3	R82.1
Associated conditions	**ICD-9**	**ICD-10**
Volume depletion (dehydration)	276.5*	E86.0, E86.1, E86.9
Effects of heat and light	992.0-992.9	T67.0*-T67.9*
Effects of thirst (deprivation of water)	994.3	T73.1*
Exhaustion due to exposure	994.4	T73.2*
Exhaustion due to excessive exertion (overexertion)	994.5	T73.3*

Abbreviations: ICD-9, International Classification of Diseases, 9th Revision; ICD-10, International Classification of Diseases, 10th Revision.
* Indicates that any subsequent digit or character is included.

and Fort Jackson, SC; while 8 installations support large combat troop populations: Fort Bragg, NC; MCB Camp Lejeune, NC; Fort Campbell, KY; Fort Shafter, HI; Marine Corps Base (MCB) Camp Pendleton, CA; Fort Cavazos, TX; Fort Carson, CO; and MCAGCC Twentynine Palms, CA. From 2020 through 2024, MCRD Parris Island/Beaufort, Fort Benning, and Fort Bragg together accounted for over 1 quarter (26.8%) of all cases **(Table 3)**.

TABLE 2. Incident Cases[a] and Incidence Rates[b] of Exertional Rhabdomyolysis, Active Component, U.S. Armed Forces, 2024

	Hospitalizations		Ambulatory Visits		Total	
	No.	Rate[b]	No.	Rate[b]	No.	Rate[b]
Total	184	14.2	280	21.6	464	35.9
Sex	.	.	.	.	.	.
Male	171	16.1	258	24.3	429	40.3
Female	13	5.6	22	9.6	35	15.2
Age, y	.	.	.	.	.	.
< 20	36	24.2	89	59.7	125	83.9
20–24	56	17.5	75	23.4	131	40.9
25–29	45	14.8	72	23.7	117	38.4
30–34	25	11.6	21	9.7	46	21.3
35–39	16	9.5	16	9.5	32	19.1
40 +	6	4.4	7	5.1	13	9.6
Race and ethnicity		.	.	.	.	.
White, non-Hispanic	77	11.6	123	18.5	200	30.0
Black, non-Hispanic	50	23.8	72	34.3	122	58.1
Hispanic	44	17.0	57	22.1	101	39.1
Other/unknown[c]	13	8.1	28	17.5	41	25.6
Service branch	.	.	.	.	.	.
Army	112	25.4	125	28.4	237	53.8
Navy	18	5.6	23	7.1	41	12.7
Air Force	15	4.7	23	7.2	38	11.8
Marine Corps	37	21.9	106	62.8	143	84.7
Coast Guard	2	5.1	3	7.6	5	12.6
Rank	.	.	.	.	.	.
Enlisted	133	12.9	178	17.3	311	30.2
Officer	29	12.0	29	12.0	58	23.9
Recruit	22	95.0	73	315.3	95	410.4
Military occupation	.	.	.	.	.	.
Combat-specific[d]	49	30.3	63	39.0	112	69.3
Motor transport	3	7.1	8	19.0	11	26.1
Pilot/air crew	4	8.9	2	4.4	6	13.3
Repair/engineering	30	8.3	35	9.7	65	18.1
Communications/intelligence	40	14.4	43	15.5	83	29.9
Health care	10	9.5	11	10.4	21	19.9
Other	48	15.9	118	39.1	166	55.0
Home of record	.	.	.	.	.	.
Midwest	19	9.7	33	16.8	52	26.5
Northeast	31	20.0	42	27.1	73	47.1
South	86	15.2	137	24.3	223	39.5
West	36	12.0	55	18.4	91	30.4
Other/unknown	12	15.2	13	16.5	25	31.7

Abbreviations: No., number; y, years.
[a]One case per person per year.
[b]Rate per 100,000 person-years.
[c]Includes those of American Indian/Alaska Native, Asian/Pacific Islander, and unknown race or ethnicity.
[d]Infantry/artillery/combat engineering/armor.

Discussion

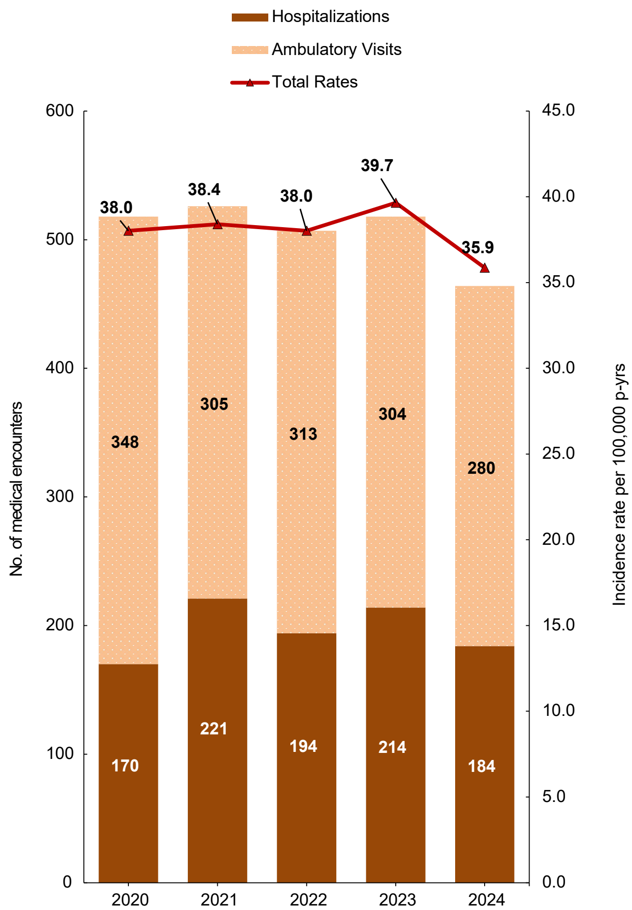
This update documents that both the absolute case count and total crude incidence rate of exertional rhabdomyolysis declined in 2024, resulting in nearly 10% reduction from the peak incidence rate observed in 2023. The percent of cases that were hospitalized also declined by 4% but remained elevated compared to the lowest rate observed in 2020, which was likely influenced by COVID-19 pandemic restrictions.

This decline in the incidence of exertional rhabdomyolysis is encouraging. As a descriptive surveillance study, however, it cannot determine the specific reasons for the observed decline. It is possible that increased awareness following the 2023 peak may have led to enhanced prevention efforts, such as improved heat injury education, acclimatization protocols, and modified training regimens. Supporting the potential impact of training modifications, the recent incident involving the Tufts University men's lacrosse team, in which 24 out of 61 student athletes developed exertional rhabdomyolysis after being subjected to a high stress workout[9] demonstrates the importance of gradual acclimatization to allow adequate physiological adaptation to increasing demands of high intensity physical fitness training.

The Air Force experienced the largest decline among all service branches for exertional rhabdomyolysis incidence in 2024. The Navy was the only service in which no decline in incidence was observed in 2024. The Navy recorded its lowest rate in 2023, but in 2024 it rebounded to a level comparable to those observed during the first 3 years of the surveillance period, 2020-2022, suggesting that this increase may reflect a return to baseline or natural annual variation rather than a true increase in incidence.

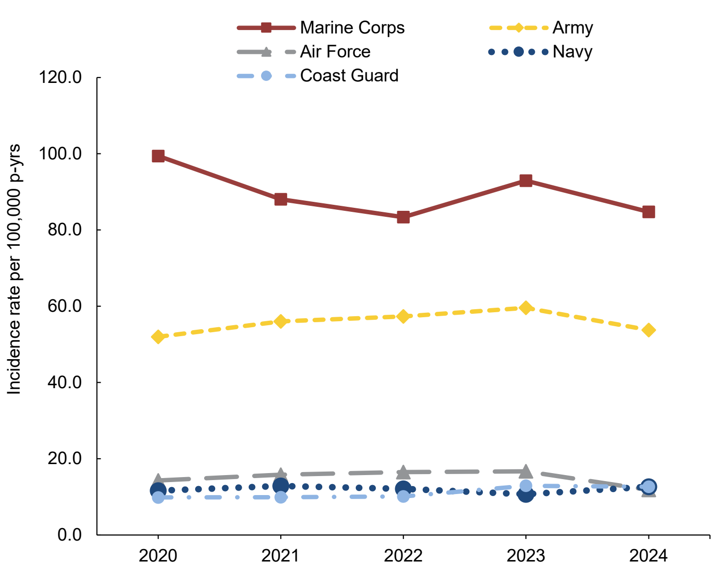
Exertional rhabdomyolysis continues to occur most frequently from mid-spring through early fall at installations that support basic combat, recruit training, or major Army or Marine Corps combat units. Recruits can be exposed to environments requiring acclimatization to high heat or humidity in hotter months,

FIGURE 1. Incident Cases and Incidence Rates of Exertional Rhabdomyolysis by Source of Report and Year of Diagnosis, Active Component, U.S. Armed Forces, 2020–2024



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

FIGURE 2. Annual Incidence Rates of Exertional Rhabdomyolysis by Service, Active Component, U.S. Armed Forces, 2020–2024



Abbreviation: P-yrs, person-years.

while soldiers and marines in combat units often perform rigorous unit physical training, personal fitness training, and field training exercises regardless of weather conditions.

Non-Hispanic Black service members continue to have persistently higher incidence rates of exertional rhabdomyolysis, approximately twice the rates in other racial or ethnic groups. This observation has been attributed, at least in part, to an increased risk of exertional rhabdomyolysis among individuals with sickle cell trait (SCT),[13-15] for which the carrier frequency is approximated at 1 in 13 non-Hispanic Black individuals in the U.S.[16-18] The rhabdomyolysis-related deaths of 2 SCT-positive service members (an Air Force member and Navy recruit) in 2019 after physical training stress this potential risk.[19,20] Although studies had shown that SCT was associated with a 54% increase in exertional rhabdomyolysis risk, no similar association was found with risk of death. According to some experts, however, those studies missed deaths due to exertional sickling, and controversies with defining exertional rhabdomyolysis, its associations with disease progression and severity, prevention, and management evidence the need for further research.[21,22] Nevertheless, changes to the 2023 TRADOC Regulation include "sickle cell trait as a risk factor" as well as updated recommendations for screening, early recognition, and prevention of exercise collapse associated with sickle cell trait (ECAST).[23]

The findings of this report should be interpreted with consideration of its limitations. A diagnosis of rhabdomyolysis alone does not indicate cause. Ascertaining the probable causes of exertional rhabdomyolysis cases was attempted by using a combination of ICD-9/ICD-10 diagnostic codes related to rhabdomyolysis with additional codes indicating effects of exertion, heat, or dehydration. Other ICD-9/ICD-10 codes were used to exclude cases of rhabdomyolysis that may have been secondary from trauma, intoxication, or adverse drug reactions. Recruit trainees were identified using an algorithm based on entry date into service, age, rank, location, and time in service, which was only an approximation and likely resulted in some misclassification of recruit training status.

Management after treatment for exertional rhabdomyolysis, including the decision to return to physical activity and duty, is a persistent challenge for athletes and military members.[21] Service members who experience a clinically confirmed exertional rhabdomyolysis event should be further evaluated and risk-stratified for recurrence before return to activity or duty.[6,24,25] Service-specific guidelines may require temporary or permanent duty restriction following rhabdomyolysis, as recently diagnosed individuals remain at a higher risk for future heat illness. The most severe consequences of exertional rhabdomyolysis are preventable with effective mitigation measures and heightened suspicion of probability when environmental conditions favor muscular injury.

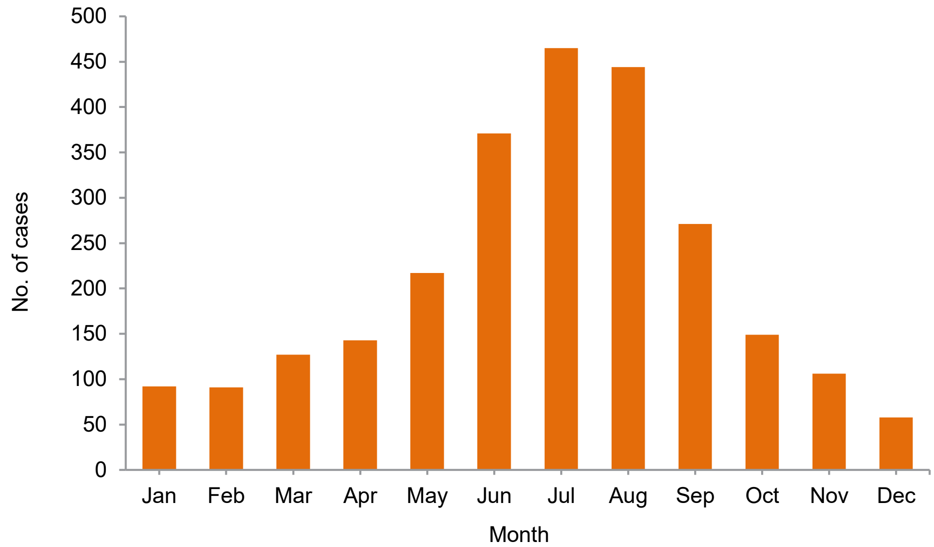
In 2024, the burden and incidence of exertional rhabdomyolysis was lower than in any other year of the 2020-2024 surveillance period, a nearly 10% reduction from the peak incidence rate observed in 2023. Continued surveillance will help determine whether these changes reflect sustained trends or temporary fluctuations. Service-specific public health and medical assets are encouraged to conduct targeted studies to identify and assess individual, operational, and environmental factors contributing to risk of exertional rhabdomyolysis, and evaluate the effectiveness of any preventive or mitigative interventions implemented. Commanders and supervisors at all levels should ensure that guidelines for heat illness prevention are consistently implemented, maintain vigilance for early signs of exertional heat injury, and intervene aggressively when exertional rhabdomyolysis is suspected.

TABLE 3. Incident Cases of Exertional Rhabdomyolysis by Installation with at Least 20 Cases During the Period, Active Component, U.S. Armed Forces, 2020–2024

Location of Diagnosis	No.	% Total
Fort Bragg, NC	278	11.0
MCRD Parris Island, SC	211	8.3
Fort Benning, GA	191	7.5
NMC Camp Lejeune, NC	119	4.7
Fort Campbell, KY	109	4.3
Camp Pendleton, CA	85	3.4
Fort Cavazos, TX	79	3.1
Fort Shafter, HI	79	3.1
JBSA-Lackland, TX	72	2.8
Fort Leonard Wood, MO	60	2.4
MCB Quantico, VA	57	2.2
Fort Johnson, LA	48	1.9
Fort Bliss, TX	47	1.9
NMC San Diego, CA	38	1.5
Fort Carson, CO	37	1.5
Fort Jackson, SC	36	1.4
NH Twentynine Palms, CA	33	1.3
MCRD San Diego, CA	29	1.1
NH Beaufort, SC	29	1.1
NH Okinawa, Japan	28	1.1
Fort Belvoir, VA	26	1.0
Fort Eisenhower, GA	21	0.8
Other/unknown locations	822	32.4
Total	2,534	100

Abbreviations: No., number; MCRD, Marine Corps Recruit Depot; MCB, Marine Corps Base; NMC Naval Medical Center; JBSA, Joint Base San Antonio; NH, Naval Hospital.

FIGURE 3. Cumulative Numbers of Exertional Rhabdomyolysis Cases by Month of Diagnosis, Active Component, U.S. Armed Forces, 2020–2024



Abbreviation: No, number.

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Update

Exertional Hyponatremia Among Active Component Members of the U.S. Armed Forces, 2009–2024

Exertional hyponatremia, or hyponatremia associated with exercise, occurs within 24 hours after physical activity due to a serum, plasma, or blood sodium concentration ([Na+]) below the normal reference range of 135 mEq/L. Hyponatremia can be fatal if not detected early and managed properly. From 2009 to 2024, 1,829 cases of exertional hyponatremia were diagnosed among U.S. active component service members (ACSMs), with an overall incidence rate of 8.4 cases per 100,000 person-years (p-yrs). In 2024, 134 cases of exertional hyponatremia were diagnosed among ACSMs, resulting in a crude incidence rate of 10.4 per 100,000 p-yrs. Female service members, those older than 40 years, non-Hispanic White service members, Marine Corps members, recruits, those in health care occupations, and ACSMs stationed in the Midwest U.S. had higher incidence rates of diagnosis for exertional hyponatremia than their respective counterparts. From 2009 to 2024, annual rates of incident exertional hyponatremia diagnoses peaked in 2010 (12.8 per 100,000 p-yrs) and then decreased to a low of 5.3 cases per 100,000 p-yrs in 2013. The incidence rate has fluctuated since then, rising from 6.1 per 100,000 p-yrs in 2017 to the second-highest level (11.2 per 100,000 p-yrs) in 2023 before decreasing to 10.4 per 100,000 p-yrs in 2024. Service members and their supervisors must be aware of the dangers of excessive consumption of water and the prescribed limits of water intake during prolonged physical activity, including field training exercises, personal fitness training, as well as recreational activities, particularly in hot, humid weather.

What are the new findings?

Incidence rates of exertional hyponatremia changed from 2023 to 2024, with the overall incidence rate decreasing from 11.2 to 10.4 per 100,000 p-yrs. Rates increased, however, in the 25-29 years age group and in the Coast Guard, while decreasing sharply among non-Hispanic Black individuals and recruits. The highest incidence rates were observed in non-Hispanic White individuals and health care personnel.

What is the impact on readiness and force health protection?

Incidence rates of exertional hyponatremia among U.S. military members have fluctuated but, in general, increased in the past decade, posing a substantial health risk to U.S. military members. Exertional hyponatremia can be fatal if not recognized promptly and treated appropriately. Military members, leaders, and trainers must be vigilant for early signs of hyponatremia and intervene immediately and appropriately, while adhering to guidelines for proper hydration during physical exertion, especially during warm weather.

Exertional hyponatremia is a relatively rare condition, but it can be fatal if not detected early and managed properly. Exertional hyponatremia is caused by increased intake of hypotonic fluids, such as water or sports drinks, before or during strenuous physical activity, including prolonged military field training and combat operations. Exertional hyponatremia can also be caused by inappropriate secretion of a non-osmotic antidiuretic hormone due to physical exertion, resulting in increased total body and free water retention.[1]

Exercising in hot weather continues to cause preventable injuries and deaths in young, healthy people.[2] Hyponatremia is particularly problematic in the military, where it can be mistaken for heat exhaustion or heat stroke. Active component military personnel are particularly susceptible to fluid and electrolyte imbalances due to intense physical exertion and demanding activities, often in hot, remote, or austere environments.[2,3]

Normal plasma sodium (Na+) concentration falls between 135 and 145 milliequivalents per liter (mEq/L), which is closely regulated, along with osmolarity, to maintain proper cell size and function.[4] Excessive intake of sodium stimulates thirst to increase body water to maintain serum [Na^+].[5,6] When a serum or plasma sodium concentration is less than 135 mEq/L within 24 hours after prolonged physical activity, hyponatremia or exercise-related hyponatremia occur.[7] There is growing evidence that hyponatremia is associated with increased morbidity, mortality, and health costs in various clinical settings and diseases.[8,9]

The incidence of hyponatremia due to a variety of activities, including endurance competitions, hiking, police training, American football, fraternity hazing, and military exercises, varies widely depending on activity duration, heat or cold stress, water availability, and consumption, and other individual risk factors.[10] Other important risk factors besides excessive fluid intake include exercise duration of greater than 4 hours, inadequate training for an exertional event, and high or low body mass index.[10] Symptoms depend on the extent and rate of decrease in serum sodium compared to baseline levels.

The fundamental characteristics of military operations, such as long-term military training and combat operations in extreme environmental conditions, mean that exertional hyponatremia continues to pose a health risk to U.S. military personnel, with the potential for significantly reducing performance and combat effectiveness. This report summarizes the frequency, rates, trends, demographic, geographic location, and military characteristics of exertional hyponatremia cases among active component service members (ACSMs) from 2009 to 2024.

Methods

The surveillance population for this report consisted of all ACSMs of the U.S. Army, Navy, Air Force, Marine Corps, Space Force, and Coast Guard who served at any time during the surveillance period, from January 1, 2009 to December 31, 2024. All data used to determine incident exertional hyponatremia diagnoses were derived from records routinely collected and maintained in the Defense Medical Surveillance System (DMSS). Those records document both ambulatory encounters and hospitalizations of ACSMs of the U.S. Armed Forces in fixed military and civilian (if reimbursed through the Military Health System) hospitals and clinics worldwide.

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 and 10th Revisions, ICD-9: 276.1, ICD-10: E87.1) and no other illness or injury-specific diagnoses (ICD-9: 001–999, ICD-10: 'A'–'U') 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 (dx1–dx3): "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).[11]

Medical encounters were excluded from case-defining events if the associated records listed diagnoses in any diagnostic position that included alcohol or illicit drug abuse; psychosis, depression, or other major mental disorders; endocrine disorders; kidney diseases; intestinal infectious diseases; cancers; major traumatic injuries; or complications of medical care. An individual could be considered a case of exertional hyponatremia only once per calendar year. Incidence rates were calculated as cases of hyponatremia per 100,000 person-years (p-yrs) of active component service.

For health surveillance purposes, recruits were identified as active component members assigned to service-specific training locations during coincident service-specific basic training periods. Recruits were considered as a separate category of enlisted service members in summaries of exertional hyponatremia by military grade overall.

Results

In 2024, 134 cases of exertional hyponatremia were diagnosed among ACSMs, resulting in a crude incidence rate of 10.4 per 100,000 p-yrs, a decrease from 11.2 per 100,000 p-yrs in 2023. From 2009 to 2024, there were 1,829 incident diagnoses of exertional hyponatremia among ACSMs resulting in a crude overall incidence rate of 8.4 cases per 100,000 p-yrs. **Table 1** presents the incident cases and rates of exertional hyponatremia according to demographic characteristics.

In 2024, female ACSMs had a higher annual incidence rate (11.7 per 100,000 p-yrs) than males (10.1 per 100,000 p-yrs), although both sexes showed a decrease. Service members aged 40 years and older showed the highest incidence rate, followed by those younger than 20 years (22.0 and 14.6 per 100,000 p-yrs, respectively). It is notable that the incidence of those aged 25-29 years increased noticeably in 2024 compared to 2023 (11.8 and 7.8 per 100,000 p-yrs, respectively). Another remarkable change was in relation to racial and ethnic groups: non-Hispanic White service members had the highest incidence rate (11.7 per 100,000 p-yrs) compared to other racial and ethnic groups, especially non-Hispanic Black service members, who previously demonstrated the highest incidence rate. As with overall 2009-2024 rates, Marine Corps members had the highest incidence rate in 2024 (14.2 per 100,000 p-yrs) compared to other services. Meanwhile, the incidence rate in the Coast Guard increased greatly, from 2.6 per 100,000 p-yrs in 2023 to 12.6 per 100,000 p-yrs in 2024.

There were 11 cases of exertional hyponatremia among recruits in 2024, an approximately 50% decrease from 2023 (47.3 to 90.2 per 100,000 p-yrs). Service members in health care occupations had the highest incidence rate in 2024, an approximately 18% increase from 2023 (12.3 to 10.4 per 100,000 p-yrs), excluding the 'other' or unknown occupation group.

Figure 1 presents annual incident cases and rates of exertional hyponatremia among ACSMs. Between 2009 and 2024, the crude annual rates of incident exertional hyponatremia diagnoses peaked in 2010 (12.8 per 100,000 p-yrs) and then decreased to the lowest level, 5.3 cases per 100,000 p-yrs, in 2013. During the ensuring decade, rates fluctuated but generally trended upward, rising from a low of 6.1 cases per 100,000 p-yrs in 2017 to a peak of 11.2 cases per 100,000 p-yrs in 2023, before decreasing to 10.4 per 100,000 p-yrs in 2024. The annual incidence of exertional hyponatremia diagnosis was significantly higher in the Marine Corps than in any other service branch **(Figure 2)**. The incidence of exertional hyponatremia fluctuated more among women than men **(Figure 3)**. During the 16-year surveillance period, 87.7% (n=1,604) of all cases were diagnosed and treated without hospitalization (data not shown).

During the surveillance period, exertional hyponatremia cases were diagnosed at more than 150 U.S. military installations

TABLE 1. Incident Cases[a] and Rates[b] of Exertional Hyponatremia, Active Component, U.S. Armed Forces, January 2009–December 2024

	2024		Total 2009–2024	
	No.	Rate[b]	No.	Rate[b]
Total	134	10.4	1,829	8.4
Sex				
Male	107	10.1	1,534	8.3
Female	27	11.7	295	8.5
Age Group, y				
<20	12	14.6	223	16.0
20–24	30	7.7	491	7.1
25–29	36	11.8	363	7.0
30–34	12	5.6	236	6.7
35–39	14	8.4	215	8.3
40+	30	22.0	301	13.2
Race and ethnicity				
White, non-Hispanic	78	11.7	1,151	9.1
Black, non-Hispanic	20	9.5	246	7.2
Hispanic	19	7.4	226	6.8
Other/unknown	17	10.6	206	8.1
Service branch				
Army	55	12.5	652	8.3
Navy	21	6.5	288	5.5
Air Force	29	9.0	369	7.2
Marine Corps	24	14.2	470	15.8
Coast Guard	5	12.6	50	7.7
Military rank				
Enlisted	81	7.9	1,130	6.4
Officer	40	16.5	417	10.8
Recruit	11	47.3	280	64.0
Military occupation				
Combat-specific[c]	18	11.1	309	10.2
Motor transport	3	7.1	39	5.5
Pilot/air crew	5	11.1	49	6.3
Repair/engineering	21	5.8	335	5.2
Communications/intelligence	32	11.5	327	6.9
Health care	13	12.3	137	7.4
Other	42	13.9	633	14.3
Home of record				
Midwest	21	10.7	327	8.5
Northeast	15	9.7	264	9.6
South	57	10.1	779	8.4
West	31	10.3	363	7.3
Other/unknown	10	12.7	96	9.5

Abbreviations: No., number; y, years.
[a]One case per person per year.
[b]Rate per 100,000 person-years.
[c]Infantry/artillery/combat engineering/armor.

and geographic locations worldwide, but 17 U.S. installations contributed 20 or more cases each and accounted for 49.9% of the total cases **(Table 2)**. Marine Corps Recruit Depot (MCRD) Parris Island, SC, reported 195 cases of exertional hyponatremia, the highest in the DOD.

Discussion

Incidence rates of exertional hyponatremia fluctuated over the past decade, increasing from 6.1 per 100,000 p-yrs in 2017 to 11.2 per 100,000 p-yrs in 2023, before decreasing slightly to 10.4 per 100,000 p-yrs in 2024. Notable changes in incidence rates of exertional hyponatremia were observed among several demographic groups in 2024 compared to 2023. Although reports on the association between sex and hyponatremia present conflicting results,[12,13] many studies report that sex is not a significant risk factor for hyponatremia.[16-17] Further investigation and ongoing monitoring may be warranted, however, to effectively prevent exertional hyponatremia, especially in women, given the greater variability in incidence in women than in men.

The age group with the highest incidence rate in 2024 was the 40 years and older age group, which had decreased considerably from 2023. According to the literature, increasing age is a strong independent risk factor for both hyponatremia and hypernatremia.[14] Unlike other age groups that showed declines compared to 2023, the incidence rate in 2024 increased remarkably in the 25-29-year age group. Investigation of the reasons for this change, to identify modifiable risk factors that can be targeted in prevention programs, is warranted.

Since 1999, differences in incidence rates between non-Hispanic White and non-Hispanic Black service members have ranged from large to small or insignificant differences.[10,18] During the 16-year surveillance period, incidence rates among non-Hispanic White service members were higher than those among non-Hispanic Black service members, in all but 6 years: 2005, 2016, 2018, 2019, 2022, 2023.

Several studies have reported conflicting results about the potential association between hyponatremia and race or ethnicity. Some studies have reported a higher prevalence in African Americans and non-Hispanic Black individuals,[19] whereas others have reported a trend of lower proportions of African American hospital admissions with hyponatremia.[15]

Unlike other service branches, 3 of which showed a decline compared to 2023, the Coast Guard showed a noticeable increase in the incidence rate of its members in 2024. There was also significant variation in incidence rates across military grade (i.e., rank), with recruits consistently having the highest incidence rates.

Several important limitations should be considered when interpreting the results of this analysis. First, there is no diagnostic code specific for exertional hyponatremia. This lack of specificity may result in inclusion of some non-exertional cases of hyponatremia, thus overestimating the true rate. 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.

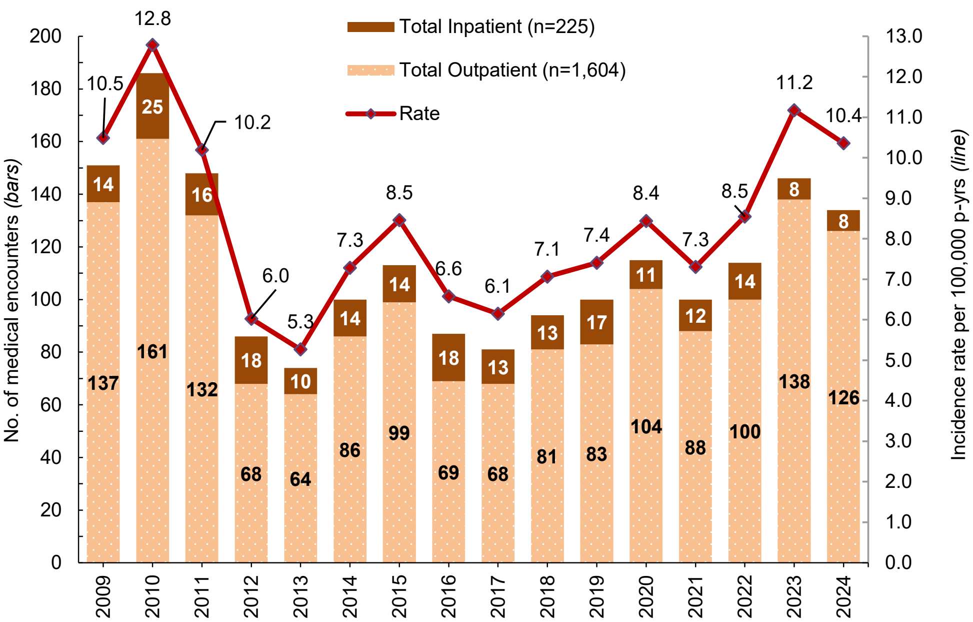
In addition, the accuracy of estimated numbers, rates, trends, and correlates of risk depends on the completeness and accuracy of diagnoses that are documented in standardized records of relevant medical encounters. Nonetheless, the decline in the number of diagnoses presenting with exertional hyponatremia may reflect increased awareness, concern, and aggressive management of early cases by military supervisors and primary health care providers.

Finally, recruits were identified using an algorithm based on age, rank, location, and time in service, which was only an approximation and likely resulted in some misclassification of recruit training status.

Given the remarkable changes from 2023 to 2024 in the incidence rate of exertional hyponatremia for numerous demographic characteristics analyzed, continued emphasis should be placed on how to effectively manage the condition, including prevention, identification, and treatment methods through close monitoring. Hyponatremia is treated primarily by managing the underlying cause (i.e., heart failure) and free water restriction,[20] focusing on pre-hospital care through rapid on-site emergency medical service assessment and hospital management in emergency and inpatient settings.[21] Depending on the physical demands of military operations and prevailing environmental conditions, replacement fluid composition may vary.[22]

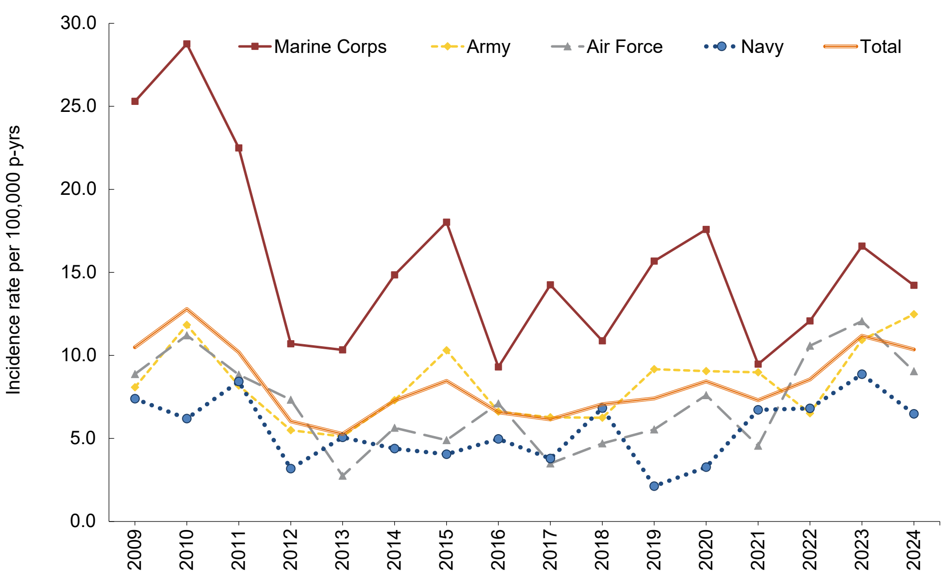
Exertional hyponatremia must be differentiated from heat illness to avoid inappropriate treatment and adverse outcomes and, instead, accurately diagnose and

FIGURE 1. Annual Incident Cases and Rates of Exertional Hyponatremia, Active Component, U.S. Armed Forces, 2009–2024



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

FIGURE 2. Annual Incidence Rates of Exertional Hyponatremia by Service, Active Component, U.S. Armed Forces, 2009–2024

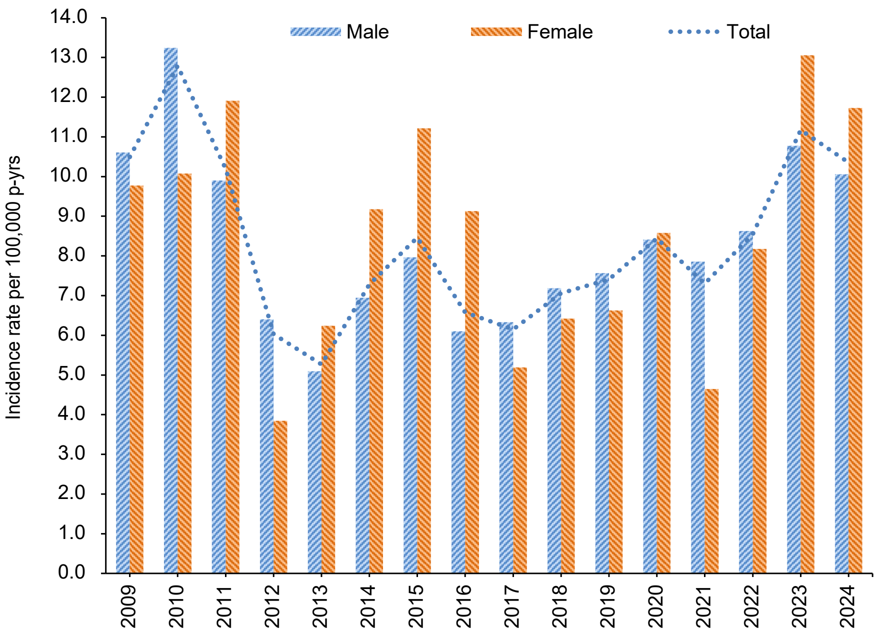


Abbreviation: P-yrs, person-years.
Note: Coast Guard not included due to small counts and unstable rates.

appropriately treat the condition based on observed signs and symptoms. Appropriately trained personnel should be able to recognize the signs of possible hyponatremia, such as excessive fluid intake, changes in mental status, vomiting, poor eating habits, abdominal bloating, and large amounts of clear urine.[2,23,24]

Due to the variety of underlying causes, individualized management based on each service member's overall health may be the best approach to prevent exertional hyponatremia. Effective and collaborative management consistent with current policy and guidance for commanders is crucial for prevention of exertional hyponatremia **(Table 3)**.[23] To reduce risk of exertional hyponatremia, service members of all ranks should be cognizant of mitigation measures such as fluid and electrolyte replacement guidelines, identification of high-risk individuals, and the importance vigilance during associated activities.[23]

FIGURE 3. Annual Incident Rates of Exertional Hyponatremia by Sex, Active Component, U.S. Armed Forces, 2009–2024



Abbreviations: p-yrs, person-years.

TABLE 2. Incident Cases of Exertional Hyponatremia by Installation with at Least 20 Cases During the Period, Active Component, U.S. Armed Forces, 2009–2024

Location of Diagnosis	No.	% Total
MCRD Parris Island/ Beaufort, SC	195	10.7
Fort Benning, GA	149	8.1
JBSA-Lackland AFB, TX	63	3.4
MCB Camp Lejeune/ Cherry Point, NC	58	3.2
Fort Bragg, NC	56	3.1
NMC San Diego, CA	52	2.8
MCB Camp Pendleton, CA	44	2.4
NMC Portsmouth, VA	44	2.4
Walter Reed NMMC, MD	44	2.4
Fort Cavazos, TX	32	1.7
Fort Campbell, KY	30	1.6
Fort Schafter, HI	28	1.5
MCB Quantico, VA	26	1.4
Fort Belvoir, VA	25	1.4
Fort Carson, CO	25	1.4
Fort Jackson, SC	21	1.1
NH Jacksonville, FL	21	1.1
Other/unknown locations	916	50.1
Total	1,829	100

Abbreviations: No., number; MCRD, Marine Corps Recruit Depot; JBSA, Joint Base San Antonio; AFB, Air Force Base; MCB, Marine Corps Base; NMC, Naval Medical Center; NMMC, National Military Medical Center; NH, Naval Hospital.
Note: Recruit training locations include Fort Jackson, Fort Benning, Fort Sill, Fort Leonard Wood, Lackland Air Force Base, Keesler Air Force Base, Coast Guard Training Center Cape May, MCRD Parris Island, MCRD San Diego, and Naval Station Great Lakes. Referral centers include Walter Reed NMMC, NMC San Diego, and NMC Portsmouth.

TABLE 3. TRADOC Recommendations[a] for Continuous Work Duration and Fluid Replacement in Warm and Hot Environments

		Easy Work		Moderate Work		Heavy Work		Very Heavy Work	
Heat Category	WBGT Index (°F)	Work (min)	Water Intake (qt/hr)	Work (min)	Water Intake (qt/hr)	Work (min)	Water Intake (qt/hr)	Work (min)	Water Intake (qt/hr)
1 (white)	78–81.9	NL[b]	½	NL[b]	¾	110	¾	45	¾
2 (green)	82–84.9	NL[b]	½	NL[b]	1	70	1	40	1
3 (yellow)	85–87.9	NL[b]	¾	NL[b]	1	60	1	25	1
4 (red)	88–89.9	NL[b]	¾	180	1¼	50	1¼	20	1¼
5 (black)	>90	NL[b]	1	70	1½	45	1½	20	1½

Notes:
1. Applies to average-sized and heat-acclimatized service member wearing the operational camouflage pattern uniform.
2. Fluid needs can vary based on individual differences (± ¼ qt/hr) and exposure to full sun or shade (± ¼ qt/hr).
3. CAUTION: Hourly fluid intake should not exceed 1½ qts.
4. CAUTION: Daily fluid intake should not exceed 12 qts.
Abbreviations: TRADOC, Training and Doctrine Command; WBGT, wet bulb global temperature; F, Fahrenheit; min, minimum; qt, quart; hr, hour; NL, no limit.
[a]Reference 23, page 24.
[b]No work limit per hour, up to 4 continuous hours.

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Reportable Medical Events at Military Health System Facilities Through Week 14, Ending April 5, 2025

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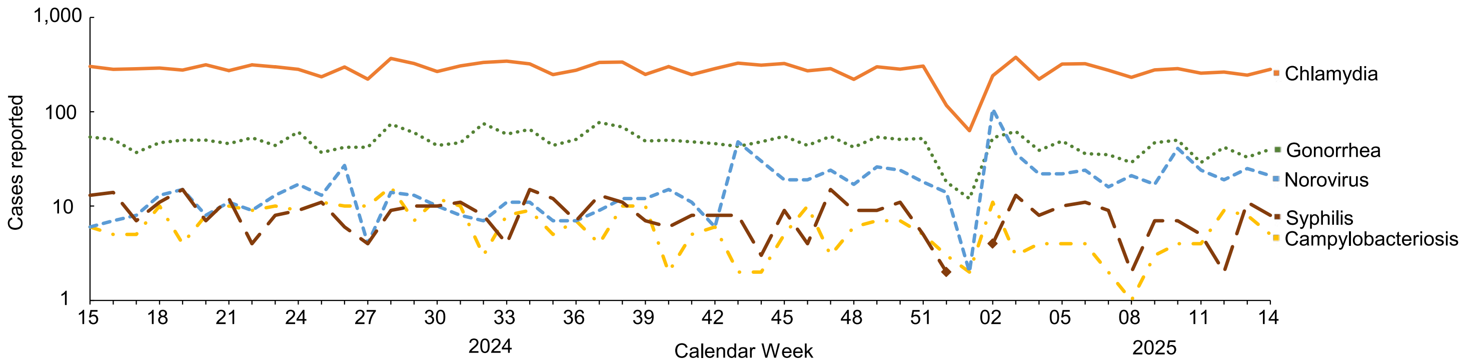
TOP 5 REPORTABLE MEDICAL EVENTS[a] BY CALENDAR WEEK, ACTIVE COMPONENT (APRIL 13, 2024–APRIL 5, 2025)



Abbreviation: RMEs, reportable medical events.

[a]Cases are shown on a logarithmic scale.

Note: No syphilis cases were reported during week 1 of 2025.

Reportable Medical Events (RMEs) are documented in the Disease Reporting System internet (DRSi) by health care providers and public health officials throughout the Military Health System (MHS) for monitoring, controlling, and preventing the occurrence and spread of diseases of public health interest or readiness importance. These reports are reviewed by each service's public health surveillance hub. The DRSi collects reports on over 70 different RMEs, including infectious and non-infectious conditions, outbreak reports, STI risk surveys, and tuberculosis contact investigation reports. A complete list of RMEs is available in the *2022 Armed Forces Reportable Medical Events Guidelines and Case Definitions*.[1] Data reported in these tables are considered provisional and do not represent conclusive evidence until case reports are fully validated.

Total active component cases reported per week are displayed for the top 5 RMEs for the previous year. Each month, the graph is updated with the top 5 RMEs, and is presented with the current month's (March 2025) top 5 RMEs, which may differ from previous months. COVID-19 is excluded from these graphs due to changes in reporting and case definition updates in 2023.

For questions about this report, please contact the Disease Epidemiology Branch at the Defense Centers for Public Health–Aberdeen. Email: dha.apg.pub-health-a.mbx.disease-epidemiologyprogram13@health.mil

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TABLE. Reportable Medical Events, Military Health System Facilities, March 2025[a]

Reportable Medical Event[b]	Active Component[c]					MHS Beneficiaries[d]
	March 2025	February 2025	YTD 2025	YTD 2024	Total 2024	March 2025
	No.	No.	No.	No.	No.	No.
Amebiasis	1	2	7	5	15	0
Arboviral diseases, neuroinvasive and non-neuroinvasive	0	0	0	0	3	0
Brucellosis	0	0	0	0	1	0
COVID-19-associated hospitalization and death	8	3	15	16	41	16
Campylobacteriosis	27	10	61	44	326	6
Chikungunya virus disease	0	0	0	0	1	0
Chlamydia trachomatis	1,100	1,116	3,425	4,289	15,651	148
Cholera	0	0	0	1	3	0
Coccidioidomycosis	2	2	4	25	53	2
Cold weather injury[e]	21	122	230	122	173	N/A
Cryptosporidiosis	5	3	16	22	82	0
Cyclosporiasis	1	0	1	0	11	0
Dengue virus infection	2	0	3	2	12	0
E. coli, Shiga toxin-producing	3	2	9	7	93	0
Ehrlichiosis / anaplasmosis	0	0	0	0	1	0
Giardiasis	7	5	22	27	98	4
Gonorrhea	164	146	523	774	2,769	19
Haemophilus influenzae, invasive	0	1	1	1	3	0
Heat illness[e]	16	14	36	57	1,275	N/A
Hepatitis A	0	0	0	1	7	0
Hepatitis B, acute and chronic	5	6	17	31	108	4
Hepatitis C, acute and chronic	2	5	7	12	29	4
Influenza-associated hospitalization[f]	4	14	37	31	54	23
Lead poisoning, pediatric[g]	N/A	N/A	N/A	N/A	N/A	9
Legionellosis	0	0	0	3	5	1
Leprosy	0	0	0	0	1	0
Listeriosis	0	0	1	0	0	0
Lyme disease	6	2	9	13	100	0
Malaria	1	0	1	3	21	0
Meningococcal disease	0	0	0	0	2	0
Mpox	1	0	2	4	14	1
Mumps	0	1	1	0	0	2
Norovirus	121	76	385	89	654	92
Pertussis	6	3	15	5	39	4
Post-exposure prophylaxis against Rabies	40	38	114	137	635	43
Q fever	0	0	0	0	3	0
Salmonellosis	8	5	18	21	160	3
Schistosomiasis	0	0	0	0	1	0
Shigellosis	3	2	7	10	53	0
Spotted fever rickettsiosis	0	2	3	0	22	0
Syphilis (all)[h]	27	29	91	172	518	12
Toxic shock syndrome	0	0	0	2	2	0
Trypanosomiasis	0	0	1	1	5	0
Tuberculosis	1	0	1	1	6	0
Tularemia	0	0	0	1	1	0
Typhoid fever	0	0	0	0	1	0
Typhus fever	0	0	1	1	2	1
Varicella	0	1	2	4	18	3
Zika virus infection	0	0	0	1	1	0
Total case counts	1,582	1,610	5,066	5,935	23,073	397

Abbreviations: MHS, Military Health System; YTD, year-to-date; no., number; *E, Escherichia*; N/A, not applicable.

[a] RMEs submitted to DRSi as of May 15, 2025. RMEs were classified by date of diagnosis or, where unavailable, date of onset. Monthly comparisons are displayed for the periods Feb. 1, 2025–Feb. 28, 2025 and Mar. 1, 2025–Mar. 31, 2025. YTD comparison is displayed for the period of Jan. 1, 2025–Mar. 31, 2025 for MHS facilities. Previous year counts are provided as the following: previous YTD, Jan. 1, 2024-Mar. 31, 2024; total 2024, Jan. 1, 2024–Dec. 31, 2024.

[b] RME categories with 0 reported cases among active component service members and MHS beneficiaries for the time periods covered were not included in this report.

[c] Service branches included in this report include the Army, Navy, Air Force, Marine Corps, Coast Guard, and Space Force, including personnel classified as Active Duty, Cadet, Midshipman, or Recruit in DRSi.

[d] Beneficiaries included the following: individuals classified as Retired and Family Members (including Spouse, Child, Other, Unknown). National Guard, Reservists, civilians, contractors, and foreign nationals were excluded from these counts.

[e] Only reportable for service members.

[f] Influenza-associated hospitalization is reportable only for individuals under age 65 years.

[g] Pediatric lead poisoning is reportable only for children ages 6 years or younger.

[h] Observed decline in syphilis cases from 2024 to 2025 may be due, in part, to updated case validation process that began Jan. 2024.

Letter to the Editor

Paul D. Rockswold, MD, MPH; Jill U. Riehl, MPH

We read with interest the report *Correlation Between Mean Temperature and Incidence of Tick-borne Diseases Among Active Duty Service Members in the Contiguous U.S., 2000–2023* by Denagamage and Mabila in the March 2025 issue of *MSMR*.[1]

We were pleased to see the Department of Defense's data systems being used to derive information for public health purposes. We noticed 3 items, however, that we think warrant attention because of how they might affect the interpretation of results. They include the potential over-diagnosis of Lyme disease, the findings between temperature and tick-borne diseases (TBDs) that are inconsistent with literature, and calculations based upon degrees Celsius rather than a temperature ratio scale with a true 0.

The potential for Lyme disease over-diagnosis is insufficiently addressed. The methods are based on encounter diagnoses, which may be based on clinical appearance with or without laboratory results. It is common for clinicians to over-diagnose Lyme disease based on symptoms and clinical findings alone, since diagnosis based solely on clinical presentation is unreliable. Several tick-borne illnesses have similar symptoms. A reaction to any tick bite, infected or not, may result in a skin response that could be mis-diagnosed as erythema migrans, the distinctive bullseye rash typically associated with Lyme disease. Southern tick-associated rash illness (STARI) is a tick-borne disease also characterized by a rash very similar to erythema migrans of Lyme disease, though it occurs most often in the southern U.S., where Lyme disease is considered rare.[2] The main vector of STARI is *Amblyomma americanum*, an aggressive species and most abundant tick in the mid-Atlantic and Southeast. The report does not adequately address how over-diagnosis limits the interpretation of results.

The geographical distribution of Lyme disease and *Ixodes scapularis* activity peaks appear to be inadequately addressed. Active surveillance data in southern Virginia show that adult *I. scapularis*, the vector of the pathogen that causes Lyme disease, is most active in the Southeast in late winter and early fall (i.e., not hot summer months).[3] Historically, Lyme disease is more prevalent in the northern and midwestern U.S.; increased Lyme disease incidence in service members in the South is inconsistent with existing literature. Even though the tick vector is seen in the South, multiple factors account for its lower Lyme disease incidence. The more notable factors include that host-seeking or questing behavior differs between *I. scapularis* in the North compared to the South, resulting in dramatic differences in Lyme disease prevalence. In the Southeast, ticks tend to feed on reptiles more than mammals. Since reptiles are inefficient reservoirs for Lyme disease spirochetes, there is lower incidence of the spirochetes in reptiles and ticks.[4] Climate change may be responsible for habitat expansion but alone is insufficient to account for the changes in Lyme disease distribution.

Additionally, we had concerns about the impact of certain assumptions on the overall conclusions and statements regarding temperature. When using a ratio scale, "equality of ratios as well as equality of intervals may be determined. Fundamental to the ratio scale is a true zero point."[5] For example, a 6-foot-tall adult is 2 times the height of a 3-foot-tall child, which matches the ratio of 2 between the values. If these 2 were to stand in a hole 2 feet deep, the top of the adult head would be 4 feet above ground level and the child's head would be 1 foot above ground level. Having them stand in a hole does not make the adult 4 times taller than the child.

Turning to the report, the text reports a 0.6ºC increase (5.3%) in overall annual mean temperature from 2000 to 2023. We assume the starting temperature is 11.3ºC, increasing to an end temperature of 11.9ºC (starting and ending temperatures were not reported). The temperature scale affects the results, however. Consider the following, where the first bullet captures what was reported, the second uses Fahrenheit, and the third uses the Kelvin scale:

- Celsius: the range from 11.3°C to 11.9°C resulted in a 5.3% increase;
- Fahrenheit: the range from 52.3°F to 55.2°F would result in a 5.5% increase;
- Kelvin: the range from 284.5K to 285.1K would result in a 0.2% increase.

Referring to the example, using Celsius and Fahrenheit is like standing in a hole: It misrepresents the reality. A calculation like this must be based upon a ratio scale with a true 0, such as the Kelvin scale, where a change of 0 K is identical to a change of 1ºC; also, 0 K equals -273.2ºC and 0ºC equals 273.2 K. This affects other areas of the report, as well. In the caption of **Figure 3a**, the 9.9% increase of annual mean temperature from 2011 to 2012 should be reported as about 0.4%. The 2.3% increase from 2015 to 2016 should be reported as about 0.1%.

Thank you for your consideration.

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In Reply:

We thank Dr. Rockswold and Ms. Riehl for their interest in our article, *Correlation Between Mean Temperature and Incidence of Tick-borne Diseases Among Active Duty Service Members in the Contiguous U.S., 2000–2023*, published in the March 2025 issue of *MSMR*.

We agree that Lyme disease may have been over-diagnosed in our study, particularly in areas where erythema migrans or similar rashes are prevalent. Following the Armed Forces Health Surveillance Division (AFHSD) Lyme disease case definition, our study sample includes unconfirmed cases from medical encounters as well as reportable medical events (RMEs) confirmed by laboratory data per the 2022 *Armed Forces RME Guidelines and Case Definitions*.[1] Despite potential over-reporting due to inclusion of unconfirmed cases from medical encounters, our study's large sample size and lengthy surveillance period allowed identification of temporal and regional patterns that can guide efforts to protect service members from Lyme disease. Future studies using exclusively laboratory data may provide more accurate incidence estimates.

We appreciate the note on how *Ixodes scapularis* behavior and host preferences affect Lyme disease distribution. As stated, Lyme disease is historically more prevalent in the northern and midwestern U.S., and our crude incidence rates reflect this pattern, as shown in **Table 1** (Northeast, 52.2 cases per 100,000 person-years; Upper Midwest, 13.3 cases per 100,000 person-years). Our adjusted incidence rate ratios (aIRRs) indicate, however, a relatively higher burden in the Southeast after controlling for climatic and demographic variables. We agree that this requires further investigation to discern if adjusting for temperature and precipitation measures alongside demographic variables accounts for such a discrepancy. Analysis of entomologic and ecological factors was beyond the scope of our study, but future research including these data may clarify how tick behavior, host preferences, and habitat influence regional variation in incidence of tick-borne diseases.

While Celsius is widely used in public health literature, we recognize that percentage changes based on a scale without a true 0, such as Celsius and Fahrenheit, can be misleading. Our intent in citing percentage increases was to contextualize changes in temperature over time, while reporting temperature in Celsius was intended to make it easier to compare our results with those of similar studies. We agree, however, that expressing changes in absolute degrees Celsius, or percent change using Kelvin, are more appropriate in this context.

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ISSN 2158-0111 (print)

ISSN 2152-8217 (online)

Medical Surveillance Monthly Report (MSMR)
Defense Health Agency—Public Health
Armed Forces Health Surveillance Division
11800 Tech Road, Suite 220
Silver Spring, MD 20904