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PURPOSE: Serious heat illness has received considerable recent attention due to catastrophic heat waves in the United States and Europe, the deaths of high-profile athletes, and military deployments. METHODS: This study documents heat illness hospitalizations and deaths for the U.S. Army from 1980 through 2002. Hospitalization data were obtained from the Total Army Injury Health Outcomes Database (TAIHOD) coded according to the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM). North Atlantic Treaty Organization Standardization Agreement codes were searched for heat injuries in an effort to detect cases that were not found during the ICD-9-CM search. RESULTS: Five-thousand two-hundred forty-six soldiers were hospitalized, and 37 died due to heat illness. Our results indicate: 1) approximately 60% reduction in hospitalization rates (fewer heat exhaustion cases) over the 22-yr period; 2) fivefold increase in heat stroke hospitalization rates (1.8 per 100,000 in 1980 to 14.5 per 100,000 in 2001); 3) heat stroke cases were associated with dehydration (17%), rhabdomyolysis (25%), and acute renal failure (13%); 4) lower hospitalizations rates among African and Hispanic Americans compared with Caucasians (incidence density ratio, 0.76 [95% confidence interval, 0.71-0.82]; 5) greater rates of hospitalizations and heat strokes among recruits from northern than southern states (incidence density ratio, 1.69 [95% confidence interval, 1.42-1.90]; and 6) greater rates of hospitalizations and heat strokes among women than men (incidence density ratio, 1.18 [95% confidence interval, 1.09-1.27]). CONCLUSIONS: Exertional heat illness continues to be a military problem during training and operations. Whereas the hospitalization rate of heat illness is declining, heat stroke has markedly increased.

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Epidemiology of Hospitalizations and Deaths from Heat Illness in Soldiers

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ABSTRACT

CARTER III, R., S. N. CHEUVRONT, J. O. WILLIAMS, M. A. KOLKA, L. A. STEPHENSON, M. N. SAWKA, and P. J. AMOROSO. Epidemiology of Hospitalizations and Deaths from Heat Illness in Soldiers. *Med. Sci. Sports Exerc.*, Vol. 37, No. 8, pp. 1338–1344, 2005. **Purpose:** Serious heat illness has received considerable recent attention due to catastrophic heat waves in the United States and Europe, the deaths of high-profile athletes, and military deployments. **Methods:** This study documents heat illness hospitalizations and deaths for the U.S. Army from 1980 through 2002. Hospitalization data were obtained from the Total Army Injury Health Outcomes Database (TAIHOD) coded according to the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM). North Atlantic Treaty Organization Standardization Agreement codes were searched for heat injuries in an effort to detect cases that were not found during the ICD-9-CM search. **Results:** Five-thousand two-hundred forty-six soldiers were hospitalized, and 37 died due to heat illness. Our results indicate: 1) approximately 60% reduction in hospitalization rates (fewer heat exhaustion cases) over the 22-yr period; 2) fivefold increase in heat stroke hospitalization rates (1.8 per 100,000 in 1980 to 14.5 per 100,000 in 2001); 3) heat stroke cases were associated with dehydration (17%), rhabdomyolysis (25%), and acute renal failure (13%); 4) lower hospitalizations rates among African and Hispanic Americans compared with Caucasians (incidence density ratio, 0.76 [95% confidence interval, 0.71–0.82]; 5) greater rates of hospitalizations and heat strokes among recruits from northern than southern states (incidence density ratio, 1.69 [95% confidence interval, 1.42–1.90]; and 6) greater rates of hospitalizations and heat strokes among women than men (incidence density ratio, 1.18 [95% confidence interval, 1.09–1.27]). **Conclusions:** Exertional heat illness continues to be a military problem during training and operations. Whereas the hospitalization rate of heat illness is declining, heat stroke has markedly increased. **Key Words:** EXTREME ENVIRONMENTS, EXERTIONAL HEAT ILLNESS, HEAT INJURY, HEAT STROKE, OCCUPATIONAL HEALTH

Serious heat illness has received considerable recent attention due to catastrophic heat waves in the United States (22) and Europe (26), the deaths of several high-profile athletes (18), and recent military deployments to extremely hot environments. Serious heat illness represents a continuum of increasing severity of heat exhaustion to heat stroke (3). Serious heat illness is often categorized as "classic" or "exertional," with the former primarily observed in sick and compromised populations and the latter primarily observed in apparently healthy and physically fit populations. Because of the populations affected by exertional heat illness, it is believed to be preventable.

Soldiers and athletes perform strenuous physical activity (thus producing high levels of metabolic heat) for extended durations in hot weather and as a result are susceptible to exertional heat illness. The military and civilian communities employ extensive heat mitigation procedures to manage heat strain and reduce the risk of serious exertional heat illness (8). These heat mitigation procedures include identifying high-risk persons, heat acclimatization, fluid and electrolyte replacement, exercise/rest guidelines, and vigilance. Despite these procedures, heat exposure still results in morbidity and mortality in these relatively young and apparently healthy populations of soldiers and athletes.

Epidemiological studies of exertional heat injury in military populations have focused on specific bases for relatively brief periods and with relatively small populations (7,9,13). Epidemiological studies of exertional heat injury in athletes have focused only on mortality and do not have sufficient information to calculate incidence (2,12). The present study examined hospitalizations and deaths from heat illness for the entire active duty U.S. Army during the calendar years of 1980–2002. Specifically, hospitalizations for heat exhaustion and heat stroke were evaluated for incident rates and trends, as well as the role of age, gender, race, and home of record. This represents the largest and most comprehensive epidemiological study of exertional heat injury.

METHODS

Data source. Data were obtained from the U.S. Army Research Institute of Environmental Medicine (USARIEM)

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Total Army Injury and Health Outcomes Database (TAIHOD) (23). The appropriate institutional review boards approved this study. This database incorporates information from, among numerous other sources, the Defense Manpower Data Center and the Individual Patient Data System. The TAIHOD database includes virtually all hospitalizations worldwide of active duty Army soldiers in military hospitals, as well as a high proportion of Army soldiers hospitalized in civilian facilities. Heat illness treated on an outpatient basis or at a battalion aid station without hospital admission are not included in this study nor are cases among nonactive duty soldiers. Recent evidence suggests that only about 11% of military patients receiving outpatient medical treatment for heat illness are actually hospitalized (10). Likewise, an unknown number of additional heat illness victims are treated in the field and do not receive outpatient medical treatment. Therefore, this study does not represent the full medical impact of exertional heat injury in the Army.

Sample. The TAIHOD was searched for hospitalizations due to the following ICD-9-CM diagnosis codes: 992.0 through 992.9 (heat cramps, heat exertion, heat stroke, heat syncope, and other unspecified) 276.0 (hyperosmolality), 276.1 (hyposmolality), 994.4 (exhaustion due to exposure), and 994.5 (exhaustion due to excessive exertion). An individual whose hospital record contained any of the above diagnosis codes was included in the study. Records including two or more heat illness diagnoses were counted once. Alternatively, if a soldier was hospitalized on two separate occasions for two causes, this was considered two hospitalizations. NATO Standardization Agreement (STANAG) codes 810–819 were searched for injuries due to excessive heat in an effort to detect any cases that were not found during the ICD-9-CM search (1). The STANAG codes also defined where an injury occurred (i.e., barracks, obstacle course, firing range, drill field, etc.).

The following information was available concerning each injured soldier: gender, age, ethnicity, race, rank, military occupational specialty (MOS), injury type, home of record, duty station (after July 1985), length of military service (total time in military at time of injury), principal diagnosis, 2nd to 8th diagnosis (when applicable), trauma code (intent and duty-relatedness), and cause of injury (activity at time of injury). Due to the large number of MOS in the Army, injured soldiers were grouped according to career management field (CMF) that collapses multiple related MOS into broader categories, such as infantry, health care, or field artillery. We divided the sample into six categories of age: 17–20, 21–25, 26–30, 31–35, 36–40, and >41. Race/ethnicity was divided based on 2000 census major categories: Caucasian, Black (African American/African origin), Asian/Pacific Islander, Hispanic, Other, and Alaskan/Native Indian. Relevant trauma codes provided information as to the duty status of an injured soldier and/or the intent of the injury. Trauma codes indicate duty status in the following way: battle wound or injury, accidental injury (includes code for off duty, schemes and exercises, other scheduled training, on duty, and unknown duty status).

Heat injury is defined as a mild to severe heat illness characterized by organ (e.g., liver, renal) and tissue (e.g., gut, muscle) injury with high body temperatures resulting from strenuous exercise. Heat exhaustion is the most common form of heat casualty and is not associated with evidence of organ damage. It occurs when the body cannot sustain the level of cardiac output necessary to meet the combined demands of skin blood flow for thermoregulation and blood flow for metabolic requirements of exercising muscle and vital organs and is associated with generalized weakness, fatigue, ataxia, dizziness, headache, muscle cramps, hyperventilation, and nausea. Heat stroke is defined as a severe illness characterized by central nervous system dysfunction, organ (e.g., liver, renal) and tissue (e.g., gut, muscle) injury with high body temperatures resulting from strenuous exercise and environmental heat exposure (8). Exertional heat injury is a relatively new diagnostic term and usually characterized as heat exhaustion. For this study, codes for heat exertion and exhaustion due to exposure were grouped together as heat exhaustion.

Data from the Defense Manpower Data Center component of the TAIHOD provided information on the composition of the Army, by year, with regard to gender, ethnicity, age, education level, CMF, and rank. These data were used as the denominator when calculating occurrence rates, which are expressed as cases per 100,000 soldiers per year. Data files were available for June and December of each year, with June files being used for analysis, as they represent the summer season. It was assumed that the demographic characteristics of hot weather exposed soldiers for rank, occupation, and age were comparable to the total Army. Before data analysis, each case was coded by year. Data were available from January 1980 through December 2002.

To address the question of possible differences in risk of heat illness based on home of record (geography), enlisted recruits from Northern States (Washington, Montana, North and South Dakota, Minnesota, Oregon, Idaho, Wisconsin, Michigan, New York, Maine, New Hampshire, Massachusetts, Rhode Island, and Wyoming) and recruits from Southern States (Arizona, New Mexico, Texas, Oklahoma, Arkansas, Alabama, Georgia, Louisiana, Florida, South Carolina, and Mississippi) were compared. We selected a subset of subjects using the following criteria: 6 months or less of service, junior enlisted ranks (E1–E3), and home of record reported as one of the above states. The home of record generally is the state of residence when the individual joined the military, though it is not necessarily the state where they were raised. Soldier origin was defined as southern if their state home of record was at or below 33° latitude, whereas soldier origin was defined as northern if their state home of record was at or above 42° latitude.

Analysis. Statistical analysis was conducted using SPSS 11.0 (SPSS, Inc) and Egret. Statistical analyses were performed separately by gender, age, and race with tables to show the crude rates. A Poisson regression model was used to calculate incidence ratios and 95% confidence intervals to assess incidence between genders, ethnicity, and between

TABLE 1. Heat illness patient characteristics (N = 5246).

Characteristics	N	Percent
Total number of cases	5246	
Gender		
Male	4521	86.3
Female	719	13.7
Age Groups		
17–20	1579	30.2
21–25	1945	37.2
26–30	900	17.2
31–35	474	9.1
36–40	224	4.3
41+	106	2.0
Race/Ethnicity		
Caucasian	3496	66.7
Black	1226	23.6
Asian/Pacific Islander	113	2.4
Hispanic	232	4.5
Other	135	2.7
Alaskan/Indian	27	0.1
Type of Injury		
Intentionally self-inflicted	2	0.3
Off duty	185	3.6
On duty*	4251	83.4
Training	3188	75
Field	765	18
Operational	298	7
Unknown	647	12.7
Home of Record		
North	3343	63.7
South	1903	36.3
Training, field, and operational types of duty*		

Asterisks signify activities (training, field, operational).

CMF. When calculating incidence density ratios for ethnicity, the reference group was Caucasians. When calculating incidence density ratio for home of record, the reference group was southern recruits. Frequency of occurrence is expressed as cases per 100,000 soldier years. Separate trends were plotted for heat injury categories. To more accurately estimate the overall rates of heat injury over time, growth models were used. Growth models were used to detect trends in heat injury before and after the Gulf War period (1991) and are reported as R^2 and P values. These models provide more accurate estimates of overall change in heat injury than the crude rates (incidence rates) estimated from the descriptive statistics.

RESULTS

Descriptions of the patients' characteristics are shown in Table 1. The total number of hospitalizations with codes for heat illness among Army soldiers was 5246 from 1980 through 2002. Approximately 86% (N = 4521) of the total hospital cases were men. Caucasians accounted for 67% of the cases (N = 3496), followed by African Americans (23%), Hispanics (4%), Asian/Pacific Islanders (2%), Alaskan/Native American (<1%), and others (2%). Approximately 40% (N = 2098) of all cases were less than 21 yr of age. Forty-four percent of all cases had 1 yr or less of military service (Fig. 1). A scheduled training (e.g., assault, basic) activity was the leading event, followed by exercises and maneuvers when heat illness occurred. A total of 84% of all cases (N = 4251) occurred on duty. Approximately 61% of hospitalization cases were due to heat exhaustion/syncope, followed by heat stroke (18%), and heat cramps

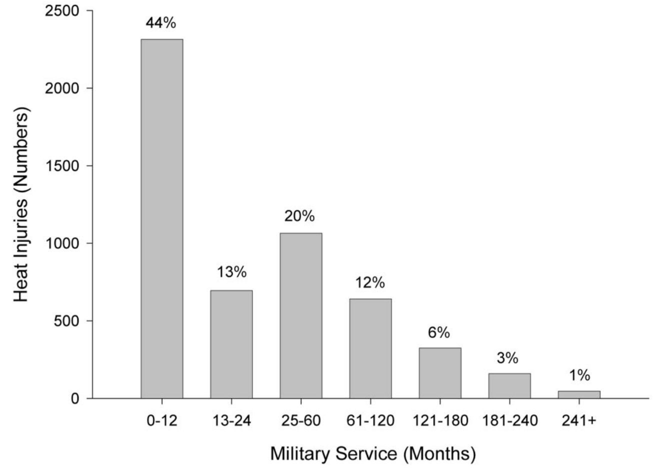

FIGURE 1—Heat injuries prevalence by months of military service in U.S. Army soldiers. The percentage is the number in that category divided by the total of heat injury cases (N = 5246).

(8%). There were 37 deaths due to heat illness, and the mortality rate was 0.3 per 100,000 soldier year during the 22-yr period.

Trends in hot weather–related injury in U.S. Army soldiers. Trends due to heat illness in U.S. Army soldiers are shown in Figure 2. From 1980 to 1991, the hospitalization rate increased from about 20 cases per 100,000 soldiers to about 55 cases per 100,000 soldiers. Hospitalizations peaked in 1990–1991, about the time of Operation Desert Storm. Since 1991, a downward trend has been observed in the total number of heat illness hospitalizations. Over the last 5 yr, the hospitalization rate has been approximately 20 cases per 100,000 soldiers.

Trends in heat illness by classification (e.g., heat stroke) from 1980 through 2002 are shown in Figure 3. After peaking in 1991, the hospitalization rate of heat exhaustion gradually declined and stabilized at approximately 10 cases per 100,000 soldiers. Similar trends were observed in both heat cramps and heat syncope. In contrast, the rate of heat stroke patients has increased over fivefold from approximately 2 cases per 100,000 soldiers to over 14 cases per 100,000 soldiers from 1980 to 1999. During 1996 to 2002, heat stroke and heat exhaustion hospitalization rates were similar, 10.51 and 10.57 cases per 100,000 soldiers, respectively. Table 2 contains the R^2 and P values from curve modeling for three different time periods: 1980–2002, 1980–1991 (before the Gulf War), and 1991–2002 (after the Gulf War). It is clear from Tables 2 and 3 that heat stroke hospitalizations have gradually increased since 1980 even as total heat injury hospitalizations have decreased. For the heat stroke cases, 17% were associated with dehydration, 25% had rhabdomyolysis, and 13% had acute renal failure. Of the 236 heat stroke cases with rhabdomyolysis, 78 also had acute renal failure. Only 6% of all heat stroke cases were dehydrated, with renal failure and rhabdomyolysis. Hyponatremia hospitalizations were low and have remained relatively constant at approximately 1 case per 100,000 soldiers per year.

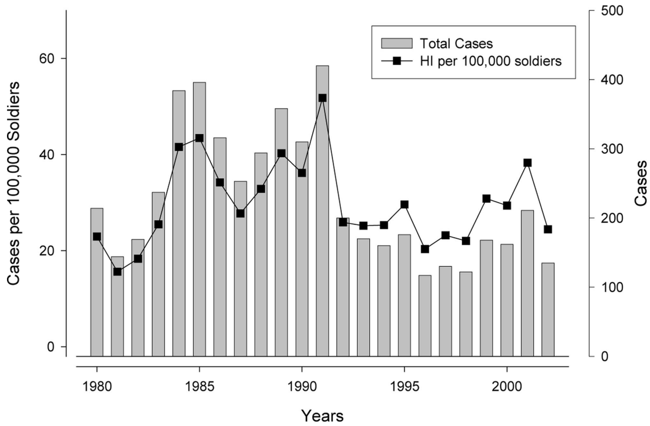

FIGURE 2—Incidence rates and total heat illness cases in U.S. Army soldiers from 1980 through 2002.

Trends in gender and race/ethnicity as risk factors for heat illness. The estimates and 95% confidence intervals for men and women stratified by race/ethnicity are shown in Table 3. In general, heat illness risk was significantly greater in women (incidence density ratio = 1.21, 95%CI: 1.09–1.40) compared with men. Of all groups, Caucasian women had the greatest incidence rate of 41.8 per 100,000 soldiers. The incidence density ratio for heat illness was the lowest in Hispanic women (incidence density ratio = 0.29; 95% CI: 0.16–0.56). In African American men, risk for heat illness hospitalization was significantly lower compared with Caucasian men (incidence density ratio = 0.76, 95% CI: 0.71–0.82).

Trends in military occupation as a risk factor for heat illness. In an effort to clarify the potential interaction between race/ethnicity and CMF on heat illness, the frequency of occurrence of heat illness by ethnicity, grouped by CMF was calculated for enlisted personnel (Table 4). Compared with other CMF, infantry soldiers and gun crewmen had the greatest risk of heat illness (incidence density ratio = 2.69, 95% CI: 1.71, 2.89), regardless of race/ethnicity. The frequency of occurrence among African Americans in the infantry/gun crews CMF was compared with the total number of African Americans in this CMF. For African Americans, infantry/gun crews were half as likely as their Caucasian counterparts to incur a heat illness (incidence density ratio = 0.6, 95% CI: 0.5–0.08) (Table 4).

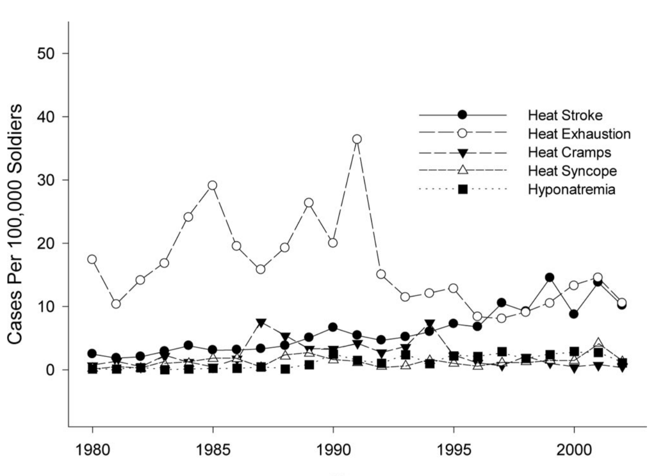

FIGURE 3—Incidence rates of heat illness by category from 1980 to 2002 in U.S. Army soldiers.

Contribution of geographical origin to heat illness among new Army recruits. In an effort to examine the contribution of geographical origin (residence) on heat illness, the frequency of occurrence of heat illness was calculated for a subset (population described in methods) of enlisted personnel. The incidence rates of heat illness among southern and northern recruits were 27.5 cases per 100,000 soldiers and 44.5 cases per 100,000 soldiers, respectively. No statistical differences in gender, race/ethnicity, age distribution, or CMF exist between northern and southern heat illness cases. Recruits from northern states are at greater risk of heat illness compared with recruits from southern states (incidence density ratio = 1.69; 95%CI: 1.42–1.90) (Table 5).

Trends in duty station among heat illness cases. Table 6 presents Army duty locations with the highest number of cases of heat illness during the study period. Georgia, North Carolina, Virginia, Kentucky, and Texas (states with Army training installations) are among the geographical locations with the highest number of heat illness cases. Due to limitations in data gatherings, duty location data of 1327 cases from July 1980 to June 1985 could not be determined, which represents about 25% of all heat illness during the study period. It should be noted that heat illness might not necessarily have occurred at that particular duty station, as it is possible that the individual soldier or his unit was deployed to another location for a mission or training purposes.

DISCUSSION

Exertional heat illness tragically still takes the lives of military personnel, athletes, and workers and is a persistent cause of morbidity. The purpose of the present study was to identify the frequency of occurrence and trends for heat illness hospitalizations and death from 1980 through 2002. This is the largest and most comprehensive epidemiological study regarding exertional heat illness in apparently healthy and active population. This study is among the first to examine race, gender, military occupational specialty, and geographical origin as risk factors. Previous studies were based on either single hospital data (14) or sampling of specific groups of hospitalized heat injury victims (7,13), so

TABLE 2. Growth curve (regression analysis) for heat injury categories.

	1980–2002		1980–1991		1992–2002	
Injury	R^2	*P*	R^2	*P*	R^2	*P*
All heat injuries	0.004	0.770	0.573	0.04	0.115	0.307
Heat stroke	0.90	0.0002	0.812	0.00003	0.73	0.001
Heat exhaustion	0.24	0.018	0.418	0.023	0.015	0.724
Heat syncope	0.251	0.015	0.477	0.013	0.499	0.015
Heat cramps	0.011	0.627	0.516	0.008	0.652	0.03

R^2 and *P* values are presented for each heat injury category and all heat injuries during the following three periods: 1980–2002 (entire observational period), 1980–1991 (prior to Gulf War), and 1992–2002 (after the Gulf War). Hyponatremia was excluded from growth modeling due to a low number of cases or no cases during several years.

TABLE 3. Frequency of occurrence of heat illness among active duty army soldiers, 1980–2002.

	Men			Women		
	Case/100,000	Cases	IDR	Case/100,000	Cases	IDR
Caucasian	33.9	3101	Reference population	41.8	395	Reference population
African American	26.1	945	0.76 (0.71–0.82)	36	281	0.86 (0.74–1.00)
Hispanic	31.8	220	0.93 (0.81–1.07)	12.42	10	0.29 (0.16–0.56)
Asian/Pacific Islander	40.6	102	1.19 (0.98–1.45)	28.3	11	0.66 (0.37–1.23)
Indian/Alaskan	30.5	22	0.89 (0.60–1.33)	34.8	5	0.83 (0.34–2.01)
Other	36.6	120	1.08 (0.89–1.29)	34.7	15	0.83 (0.49–1.39)

An active duty army soldier is an enlisted member or commissioned officer that is currently on active duty to include members of the army reserves that were activated for purposes of war or disaster relief. IDR, incidence density ratio.

have provided only minimal epidemiological information (9,17). The most often reported evidence of heat illness cases in the United States and other military settings are case and case series reports. Recently, Hakre and colleagues (10) in Marine Corps recruits showed that clinical and laboratory factors are important predictors of hospitalization for exertional heat illness.

Although many factors that contribute to exertional heat illness are fairly well understood, many of the cellular and molecular pathways are not. In fact, exertional heat illness may involve multiple pathogenic origins including tissue hyperthermia and ischemia, cytokine disturbances, disruptions in cellular protective mechanisms, and apoptosis (3,16,19). Likewise, factors such as lack of heat acclimatization, poor physical fitness, dehydration, high body mass, specific genotypes, drug use, muscle injury, and prior illness can modify individual sensitivity to these pathogenic events (4,9,13). Heat illness prevention programs focus on heat acclimatization programs, and fluid and electrolyte replacement, and these heat mitigation practices have likely led to the dramatic reduction (60 per 100,000 soldiers in 1991 to 10 per 100,000 soldiers in 2002) in heat illness hospitalizations (8). Improved medical treatment practices (like rapid and aggressive body cooling) might also contribute to the reduced hospitalization rate.

Trends in deaths and heat stroke hospitalizations. Another indication of improved prevention and treatment practices is a reduction in the number of heat illness deaths over the past 22 yr. Furthermore, the mortality rate of heat illness has remained relatively low at 0.3 per 100,000 soldier years over the past 22 yr (37 deaths). In comparison, Malamud et al. (15) reported 125 deaths from heat illness during U.S. Army basic training between 1941 and 1944. In 2002, the athletic community reported a reduction in the number of heat illness deaths during the past 40 yr (2); however, in the last year, a press release by American College of Sports Medicine suggested that the fatality rate for heat illness is increasing. Factors such as increased use of dietary supplements, coaching staff not trained in preventive measures, and lack of heat acclimatization were cited. Paradoxically, while heat illness hospitalizations and deaths have declined, there has been a constant and substantial increase in heat stroke hospitalizations (from a low of 1.8 per 100,000 soldiers in 1981 to 14.5 per 100,000 soldiers in 1999).

The increase in heat stroke hospitalizations may reflect an increased incidence rate. During the past 20 yr, there has been an increased emphasis on running activities in military training (8), and there has been an increased use of nutritional supplements (2). Each of these might contribute to more heat stroke cases. Another possibility is the increased emphasis on maintaining hydration to sustain exercise performance might allow compromised subjects to avoid heat exhaustion and continue to exercise until more severe heat injury or stroke occurs. Evidence to support this is that 17% of heat stroke cases were dehydrated, and it is likely that 20 yr ago this percentage would have been much higher (2).

Race/ethnicity. We found that African Americans and Hispanic Americans are less likely than Caucasians to be hospitalized for heat illness. Stallones et al. (24) reported over 40 yr ago that male Caucasian basic trainees had a higher frequency and incidence rate of heat illness compared with African American males. They also found that male Caucasian and African American basic trainees had heat injury attack rates of 12.5 per 1000 soldiers and 5.6 per 1000 soldiers, respectively, during summer months at Camp Chafee, Arkansas. Since this early work by Stallones and colleagues (24), no studies have examined race as a predictor for exertional heat illness in Army personnel. In male Marine recruits, Gardner and colleagues (9) suggested that

TABLE 4. Frequency of occurrence of heat injury illness among active duty soldiers by career management field.

	Caucasians	African Americans	Hispanic Americans	IDR (95% CI)	IDR (95% CI)
Career Management Field	Cases/100,000	Cases/100,000	Cases/100,000	C vs AA	C vs HA
Infantry/gun crews	56.4	38.6	52.0	0.6 (0.5, 0.8)	0.9 (0.8, 1.1)
Service/supply	44.3	21.4	24.2	0.5 (0.4, 0.6)	0.5 (0.3, 0.9)
Health care	33.7	38.9	21.2	1.2 (0.8, 1.7)	0.6 (0.3, 0.9)
Comm/intelligence	30.0	24.6	24.7	0.8 (0.6, 1.0)	0.8 (0.5, 1.3)
Technical/allied special	29.8	40.0	14.6	1.3 (0.9, 2.0)	0.5 (0.2, 0.9)
Craftsworkers	21.3	27.1	24.9	1.3 (0.8, 2.1)	1.2 (0.4, 3.8)
Electrical/mechanical	21.1	19.0	20.3	0.9 (0.7, 1.1)	0.9 (0.8, 1.1)
Support/administration	19.7	20.2	16.7	1.0 (0.8, 1.2)	0.8 (0.6, 1.3)
Electrical equipment	17.1	19.8	30.3	1.1 (0.8, 1.7)	1.8 (0.9, 3.3)

C, Caucasian; AA, African American; HA, Hispanic American; IDR, incidence density ratio.

TABLE 5. Characteristics of heat illness patients from selected northern and southern states.

	South	North
No. of cases	365	339
Percent of Army recruits	32.50	18.30
No. of soldiers 1980–2002	1,322,652	745,903
Risk ratio		1.7 (1.4–1.9)
Sex	*N*	*N*
Men	286	248
Women	79	61
Race/Ethnicity	*N*	*N*
Caucasian	232	266
African American	98	31
Hispanic	19	9
Age (yr)	*N*	*N*
17	4	3
18	67	72
19	88	91
20	86	59
21	44	33
22	17	22
23	15	14
24	15	5
25	8	6
<26	21	20
CMF	*N*	*N*
Infantry/gun crews	118	112
Service/supply	15	27
Health care	29	11
Comm/intelligence	9	8
Technical/allied special	32	31
Craftsworkers	26	27
Electrical/mechanical	1	2
Support/adminstration	79	76
Electrical equipment	15	12
Length of stay (d)	2.5 ± 4.8	2.7 ± 3.9
Length of stay (range)	0–46	0–33
Period of injury (m)		
January to May	53	43
June to August	266 (73%)	254 (75%)
September to December	46	42

Northern states are Washington, Montana, North and South Dakota, Minnesota, Oregon, Idaho, Wisconsin, Michigan, New York, Maine, New Hampshire, Massachusetts, Rhode Island, and Wyoming. Southern states are Arizona, New Mexico, Texas, Oklahoma, Arkansas, Alabama, Georgia, Louisiana, Florida, South Carolina, and Mississippi.

race is only a weak predictor of heat illness risk. However, due to small numbers of African Americans, Gardner and colleagues (9) combined all non-Caucasian categories and compared them with Caucasians.

DeGroot and colleagues (5) found that African American men and women suffered cold injury hospitalization at 4 times and at 2.2 times the rate of their Caucasian counterparts, respectively. Taken together with recent work by DeGroot and colleagues (5), our data suggest that race and ethnicity may be a risk factor for both cold and heat injury. Anthropomorphic differences between races might help account for this observation. The larger surface area-to-mass ratio often seen in many African Americans would provide thermoregulatory advantages with tropic (as long as ambient temperature is less than skin temperature) but thermoregulatory disadvantages with cold (25) climatic exposures.

To determine the influence of military occupational factors, we analyzed the frequency of heat illness by CMF and ethnicity. Despite significant variation in the rate of heat illness between CMF, Hispanic, and African Americans had lower frequency of heat illness compared with Caucasians. Infantry soldiers had the greatest risk of heat illness, whereas soldiers in administrative and support jobs had the lowest risk, regardless of race/ethnicity categories, a finding likely explained by more exposure to high ambient temperatures.

Geographical origin. Recruits from northern states are more susceptible to heat illness than recruits from southern states. In addition, the majority of these heat injuries occurred during the summer months (June, July, and August) in the northern and southern recruits, 75% and 73%, respectively (Table 5). Being unacclimatized to hot weather has been identified as an important factor in heat intolerance and heat illness. However, although heat acclimatization is rapidly induced and is believed to be essentially complete within 2 wk, recent evidence suggests there may be additional advantages from many weeks of heat exposure combined with physical activity (20). Basic training in the U.S. Army employs staged exercise-heat exposure to induce acclimatization; however, some advanced specialty training as Airborne and Ranger do not schedule heat acclimatization and immediately initiate intense training. Therefore, soldiers reporting to basic training from cooler climates during summer months might be at greater risk for heat illness.

Gender. Women are at greater risk of heat illness than men (incidence density ratio, 1.18 [95% confidence interval, 1.09–1.27, $P < 0.001$]. Specifically, Caucasian women were admitted for heat illness four times more often than any other group. Dellinger and colleagues (6) previously reported greater risk of heat injury in women performing National Guard duties during a flood relief mission in Illinois. Additionally, we found race/ethnicity differences in heat illness hospitalization in women. If men and women are matched for physical fitness and heat acclimatization status, then little differences exist for their ability to thermoregulate during exercise-heat stress (21).

CONCLUSIONS

This is the largest and most comprehensive study of exertional heat injury. Our results for the U.S. Army indicate: 1) approximately 60% reduction in heat illness hospi-

TABLE 6. Frequency of heat illness by geographic location.

Location	Cases	Percent
Georgia	615	15.7
North Carolina	279	7.1
Virginia	254	6.5
Kentucky	247	6.3
Texas	214	5.5
Germany	157	4.0
Alabama	123	3.1
South Carolina	115	2.9
Louisiana	107	2.7
Oklahoma	100	2.6
Hawaii	81	2.1
California	78	2.0
South Korea	72	1.8
Washington	67	1.7
Kansas	51	1.3
New York	51	1.3
Missouri	50	1.3
Colorado	44	1.1
New Jersey	40	1.0
All other states/countries	1174	30.0
Total	3919	100.0

Bad or missing codes ($N = 1327$).

talizations rates (representing fewer heat exhaustion cases) in the last decade; 2) eightfold increase in heat stroke hospitalizations rates in the last two decades, from about 1.8 per 100,000 population to 14.5 per 100,000 population; 3) heat stroke cases were associated with dehydration (17%), rhabdomyolysis (25%), and acute renal failure (13%); 4) lower hospitalizations rates among African and Hispanic Americans compared with Caucasians (incidence density ratio, 0.76 [95% confidence interval, 0.71–0.82]); 5) greater rates of hospitalization and heat stroke cases among recruits from northern than southern states (incidence density ratio, 1.69 [95% confidence interval, 1.42–1.90]); and 6) greater rates of hospitalization and heat stroke cases among women than men (incidence density ratio, 1.18 [95% confidence interval, 1.09–1.27]). Although the hospitalization rate for total heat injury cases is declining, the heat stroke rate has markedly increased since 1980.

The views, opinions, and findings contained in this publication are those of the authors and should not be construed as an official Unites Sates Department of the Army policy, position, or decision, unless so designated by other documentation.

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