

Although the highest incidence occurred in hot climates (Cyprus and Gibraltar) the majority of cases (69%) occurred in the temperate climates of UK and Germany. This further demonstrates the limitations of guidance for prevention that relies solely on measures of environmental heat. It also reinforces the importance of endogenous heat production. However comprehensive education can be effective. This was demonstrated during the deployment of troops to the Middle East during the Gulf War in 1991 which resulted in only 8 admissions to hospital for heat illness.

A review of heat casualties occurring in Cyprus for the period 1989-1992 reflected many other studies in that the majority of casualties occurred during the summer months (9). Military activities were a much more common cause of cases than sporting activities. Over the period studied there was a reduction in the WBGT reading at the time of the incident which was presumed to be associated with improved awareness of the guidelines for the prevention of heat casualties. The peak number of cases occurred at WBGT readings between 29-30.9°C (84.2-87.6°F). However there were 10 incidents (26%) which occurred at WBGT indices below 26°C (78.8°F) when the restrictions would not have been in force.

These studies demonstrate the value of a continuous surveillance system to define the problem of heat illness in the military population. The majority of UK service personnel are stationed in temperate climates and so guidelines for the prevention of heat casualties based on WBGT indices above 26°C (78.8°F) will not be applicable. All cases occurring at these temperatures are the direct result of physical exercise though there may be associated factors such as concurrent illness, dehydration, lack of food etc. The study from Cyprus shows that the guidelines based on WBGT index are valuable in hot climates but that the guidelines may need to be revised to reduce the cases occurring between 29-30.9°C (84.2-87.6°F) when some discretion for the planning of physical exercise is permitted.

The American Experience

The majority of analyses associated with the Second World War have used death from heat illness as the inclusion criteria in the analysis. The next logical step was to use either admissions to hospital or numbers seen in primary care for entry into the study and to correlate this with a measure of environmental heat load. Such a study (10) was conducted at Fort Lee using the Effective Temperature (ET). This paper recommended the suspension of all training activities when the ET was greater than 83°F but no account was made for acclimatisation. A more detailed analysis of the problem in the US Army (11) was set up to examine the value of a measurement of temperature which they called the 'modified Effective Temperature' (calculated by 0.3 Globe Temperature + 0.7 WBT). Heat casualties were more common in camps with basic trainees and

particularly those who were overweight or were suffering from a concurrent illness. Furthermore local epidemics were identified that were caused by commanders who restricted water intake. This finding was reinforced in a further paper (12) which showed that more than 50% of reports of heat casualties occurred in association with another casualty thus the majority of heat casualties were actually small epidemics. The occasional sporadic casualty occurred as a result of individual susceptibility which could not be prevented by rigid guidelines. This paper compared the current indices of environmental heat load, the Corrected Effective Temperature (CET) and, the Modified Effective Temperature (called the Globe Wet Bulb Effective Temperature in this paper). It was found that the daily maximum Dry Bulb Temperature (DBT) gave the best correlation with the occurrence of heat casualties with a threshold of 90°F (32.2°C). However the training camp where this study was undertaken showed little variation of WBT which would have affected the calculation of all the heat indices tested.

The US armed forces had a conscript army in the 1950s and was committed to world wide deployment, particularly to Korea. Consequently large numbers were going through basic training. The US Navy and Marine Corps had 25 deaths from heat prostration or sunstroke between 1942 and 1953 with a range of incidence of heat prostration of 56.8-16.0 per 100,000 per year and sunstroke of 9.1-1.5 per 100,000 per year (13). The US Marine Corps initiated a research program to develop guidelines for the prevention of heat casualties in 1954 (60,61,62). It is the research that is the most widely quoted in the context of the prevention of military heat casualties. Six areas were identified for study (Table 2).

Table 2
Study Areas for Investigation of Heat Illness (13)

- a. The metabolic heat loads due to various forms of military training.
- b. The climatic heat loads on trainees, due to temperature, radiation, humidity and wind. These four environmental factors must be integrated into a practical index that can readily be measured in the field.
- c. The total heat load (metabolic plus climatic) and the resulting heat stress or strain on trainees.
- d. The threshold heat limits at which disabling heat symptoms begin to appear in basic and advanced trainees, calling for a reduction in physical activity.
- e. The upper heat limits beyond which heat injury will occur calling for a stop in physical activity.
- f. The epidemiology of subclinical and clinical cases of heat diseases.

In support of this research a new index of environmental heat load was developed, the 'Wet Bulb-Globe Temperature (WBGT) Index'. The initial calculation for this was 0.7 psychrometric wet bulb temperature and 0.3 black globe temperature but during the course of the experiments the calculation was

index, enables the risk of heat casualties to be quantified. However these investigators were able to strictly control physical activity within a structured training programme. Clearly this is relevant for the induction of recruits into the military system. It is much more difficult to develop workable guidelines that may be used when troops are deployed on exercise or operations.

In 1950 during the early stages of the Korean War a US Marine regiment was deployed from northern California to Pusan in South Korea. The force was involved in combat operations immediately on arrival without time to become acclimatised. Consequently 17 heat casualties were admitted within one week of arrival (17). In 1958 the Marines experienced a similar problem deploying in Lebanon in July. As a result the US Army conducted several field trials to test the effects of acclimatisation to heat on physiological and military performance in hot climates. In spite of this, in the Vietnam War the US Army suffered 5.4 heat casualties per 1,000 troops during the summer months (18). The risk factors identified in a series of hospital admissions for heatstroke collected in 1975 were similar to those reported by Minard. The majority of cases had come from Northern states (73%), they occurred during the early part of training (60%) and during or immediately after heavy exercise (93%). Although the WBGT recorded was greater than 28.3°C for 83% (10/12) of cases, one case occurred at 24.4°C and one at 13.9°C, demonstrating the range of environmental temperature that can cause heatstroke.

Further studies have been undertaken to validate the efficacy of the guidelines originated by Minard. A review of cases of heatstroke admitted from Fort Dix, a basic training camp in New Jersey, found that 7 of 8 cases occurred at WBGT indices below 88°F (31.1°C), which was the current recommended level to reduce physical activities (19). A further analysis of all heatstroke reports in the US Army for 1975 found 10 out of 14 cases occurred at temperatures below that recommended for action. It has been postulated therefore that complete prevention of heat casualties is impossible.

Further research has demonstrated that the number of heat casualties can be reduced by explicit instruction to commanders and their troops and the provision of a measure of environmental heat load to junior commanders. A comparison between troops receiving lectures, a 'Botsball' (which measures the Wet Globe Temperature) and non-indoctrinated troops found a reduction in heat casualties from 9.1% to 4.2% during one training exercise in 1980 (20). A similar investigation was conducted the following year demonstrating a casualty rate of 15/1000/day (for six days) in the control group and 7/1000/day in the group receiving detailed 'heat indoctrination'. On the basis of this the heat guidelines were amended to include a work rest cycle and guidance on the volume of water needed as fluid replacement (Table 4). However the value of the Bots ball was considered to be limited as there was substantial variation

in the difference between the Botsball reading and the WBGT.

Table 4
Guidelines for Exercise in Heat (67)

Heat Condition	Botsball WGT °F (°C)	Water intake (quarts/hr)	Work/rest cycle (min)
Green	80-83 (26.6-28.3)	0.5-1.0	50/10
Yellow	83-86 (28.3-30)	1.0-1.5	45/15
Red	86-88 (30-31.1)	1.5-2.0	30/30
Black	>88 (31.1)	2.0	20/40

Botsball readings were assumed to be approximately 2°F less than WBGT index.

The research conducted in the USA has been the catalyst for the development of a simple measure of environmental heat load and the development of guidelines to direct commanders in measures to reduce heat casualties in large populations. However the environmental heat load is not the only factor to be considered, particularly for troops on exercise or operations. Dehydration, lack of food, lack of physical fitness and lack of sleep will all lower the tolerance to heat load imposed by exercise. Indeed 50% of casualties reported in the last study occurred during periods of intense activity. Furthermore there are individuals who are uniquely susceptible to heat illness at very low environmental temperatures and it is very difficult to identify those prospectively.

The Experience of other Countries

The other main country contributing to the literature of heat illness is Israel. There is wide variation in the climate of Israel from mountain to desert conditions. The effects of heat on military operations have had a significant impact on the Arab-Israeli conflicts. The importance of adequate water is stressed in Israeli doctrine. The Israelis have investigated the use of the 'Discomfort Index' as a measure of environmental heat load (Table 5).

Table 5
Discomfort Index

Dry bulb °C + Wet Bulb °C 2	
D1	Heat Load
<22	None
22-24	Light
24-28	Moderate
>28	Severe

The Cumulative Discomfort Index is calculated by adding the excess of Discomfort Index above 24 points for each hour of a given period (69). Thus a total environmental heat load can be obtained for an activity.

A review of 36 cases admitted to hospital between 1956-1966 with heatstroke found that all cases occurred during the summer months, all were associated with physical exercise and the intake of fluid had been inadequate to compensate for sweat losses (21). The associated factors of a concurrent illness, lack of physical fitness and lack of acclimatisation were also found.

The guidance for the prevention of heat casualties includes the requirement to have medical personnel supervising events involving strenuous physical activity. It was found that no cases of severe heat stroke occurred when a physician was present at the site of physical exertion (22). A good correlation was demonstrated between the Discomfort Index and the WBGT, however the assessed risks from thermal stress have been based on a much stricter scale (Table 6). The importance of adequate hydration is stressed, recommending that the colour of urine produced by participants should always be very light yellow.

Table 6
Risk of Thermal Stress by WBGT Index (22)

(°C)	
WBGT<18	low risk
WBGT 18-23	moderate risk
WBGT 23-28	high risk
WBGT >28	very high risk

There are two other epidemiological reports from military forces. The incidence of heat casualties in the Indian Armed Forces was reported in 1974 (23). This was an analysis of heat casualties reported for the years 1963 and 1964. Approximately 90% of casualties occurred during basic training. This was often the result of recruits not being used to severe physical work in hot conditions. However, ignorance on the part of unit commanders restricting water intake during forced marches was also a major factor.

The incidence of heat casualties in the Singapore Armed Forces was reviewed in 1991 (24). The medical services noted a rise in the incidence of heat casualties from 1984 to 1987. In 1986 deliberate preventive measures were introduced to try to decrease the incidence of heat casualties. This led to a fall in incidence from 6.9/1000 in 1987 to 5.01/1000 in 1990. The prevention program included education to all recruits, trainers and doctors, revision of military training syllabi and a standard protocol for the treatment of cases. A clear association between incidence of heat illness and WBGT was shown with peaks during the hotter months of the year.

These studies, conducted after World War II, have recognised the importance of heat illness as a preventable injury. It will occur in young men only as a consequence of exercise combined with environmental heat. The relationship between these two factors is not precise and

there is wide individual variation. There have been several efforts to develop guidelines for unit commanders which will reduce the risk of heat casualties. Implicit in these guidelines has been the inclusion of a measure of environmental heat of which the WBGT Index is most widely used. It has been recognised that many heat casualties occur in clusters and often this can be attributed in retrospect to an error of judgement. However, it is clear that cases will occur at low environmental temperatures and that there are some individuals who are relatively intolerant of heat.

Conclusions

Perhaps the best method to identify further areas of research in heat illness in the military would be compared to the current situation with the objectives of the program initiated by Minard (Table 2). Much has changed since this research was undertaken. Most military forces utilise body armour for the reduction of casualties from low velocity missile fragments. Protection from Nuclear, Biological and Chemical agents is almost invariably required. The load carrying systems used have changed. Thus the data collected on the metabolic heat generated during various military activities in the 1950s will be invalid today. The exact figures for this are meaningless but an index relating activities could provide one aspect of risk assessment.

The assessment of the validity of the studies presented must establish what the authors are trying to prove. It is obvious that death or serious morbidity from heat illness is a tragedy and clearly every effort should be made to prevent this. Fortunately such deaths are uncommon. The epidemiological studies have developed the endpoints chosen have progressed from death, through hospital admission to medical attendance. However, is hospital admission a suitable endpoint for studies that aim to establish the safe levels for exercise in heat? Raised core temperature may be chosen but what level is acceptable? A raised core temperature alone is not a measure of the severity of heat illness, particularly at the levels that would be ethically acceptable for research. Physiologists have shown that core temperature will increase with environmental temperature and that this effect is magnified if the subject is exercising (25). But it has also been shown that trained athletes can tolerate high core temperatures and yet not collapse with heat illness (26). Thus core temperature alone cannot be taken as an endpoint in epidemiological studies. Symptoms and signs of heat illness can be useful if severe, but in mild cases the differences between heat exhaustion and exhaustion from exercise alone is very difficult to define. Therefore individuals might be classified as having heat exhaustion in hot climates and just labelled as unfit in a cooler environment.

The best measure should consider an aspect of the soldier's ability to perform his task. Thus a soldier who is unable to complete a military task due to the effects

exercise in the heat is a military casualty irrespective of his core temperature or the exact clinical presentation.

Epidemiological studies aim to establish an incidence for heat illness and then to correlate it with various parameters. In large studies simple estimates of the numbers of soldiers undergoing training or operations may suffice. However small studies should attempt to measure the population exposed to the same conditions as the index case. Only this level of precision will enable the accurate correlation between heat illness and other factors.

association between numbers of casualties and environmental heat will not detect a true relationship. This can only be achieved if the incidence of heat casualties (cases per number of soldiers exposed) is studied. There are no such reports in the literature.

However, these studies quoted have enabled the identification of a number of risk factors for the development of heatstroke (Table 7). These are easy to identify in retrospect. The difficulty arises in applying them prospectively in order to identify which individuals from a group might be at a relative increased risk of heat

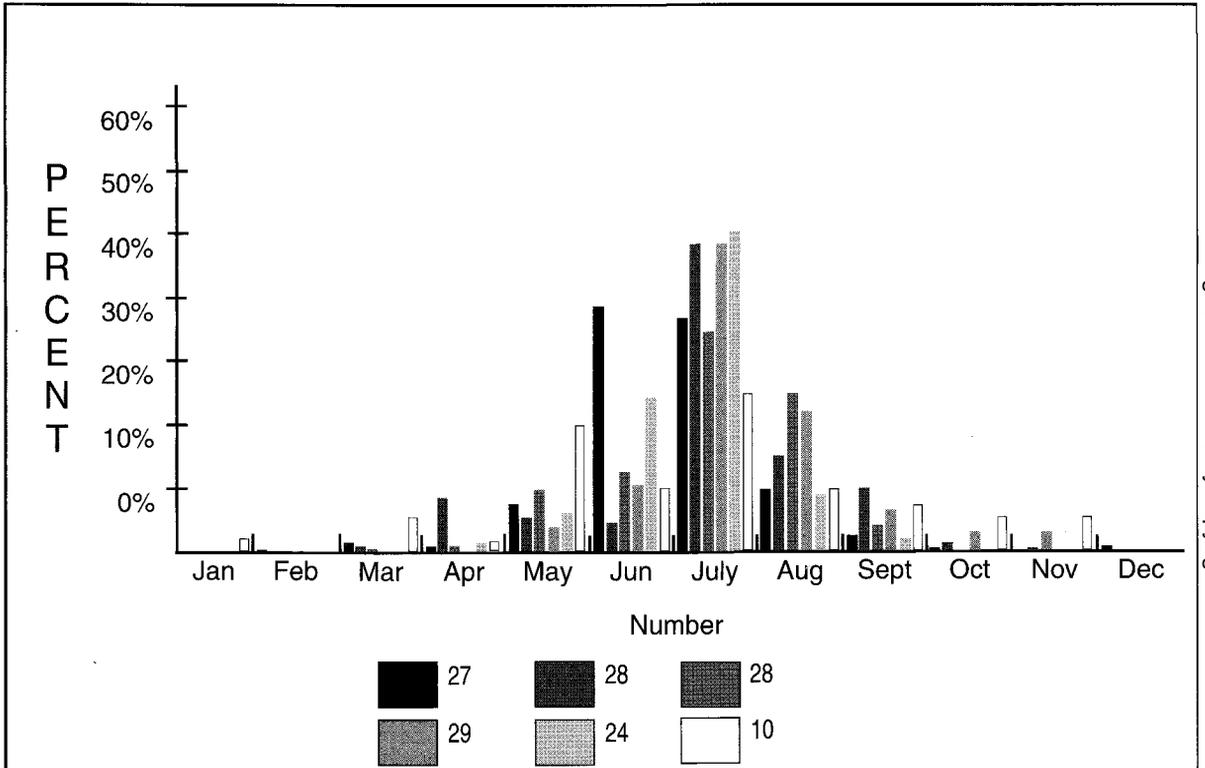


Fig 1. Distribution by Month (percent of reported cases)

Figure 1 shows the monthly distribution from a number of studies conducted in the Northern Hemisphere. There is a clear correlation between the incidence of heat illness and season, and therefore environmental temperature. There is less evidence available for a predictable association with any specific measure of environmental heat. There are no recent field studies available comparing environmental temperature measurements and the rise in core temperature associated with exercise. Therefore it is not clear which measure of environmental temperature actually most closely models the physiological load on the clothed soldier. The introduction of guidelines that aim to reduce exercise intensity in hot weather will reduce the numbers of soldiers exposed to risk. Thus a simple

illness and removing them from the activity. It is therefore easy to develop guidelines to restrict activities in extremely hot weather, but in fact these conditions are not common. The challenge is to develop guidelines that can be applied in common conditions, even temperate climates, that have prognostic value to individuals. The risk factors have been divided into those that affect individuals and those that affect groups. The exact division may be blurred, particularly if the group is not a homogenous military unit. However some susceptible individuals may be identified on the basis of their medical history. Most military forces have a system of allocating medical categories to individuals which can incorporate an element of fitness to serve in hot climates.

Unfortunately epidemiological studies show that the concurrent diseases that increase risk are often trivial, such as viral illnesses or mild gastroenteritis that are either unrecognised or ignored. Thus detailed health screening prior to intense exercise would not be easily undertaken. Certain high intensity activities such as selection for airborne forces significantly increase risk and close medical surveillance might be appropriate in these circumstances.

Table 7
Risk Factors for Heatstroke (20)

Individual	Age Drugs eg anticholinergic drugs Alcohol Concurrent illness Past history of heat illness Lack of physical fitness
Group	Lack of sleep Lack of food Lack of water Acclimatisation Environmental heat Protective clothing

Military operations and training have to be undertaken whatever the environmental limitations, thus it is not possible to forbid activity except when the risk can be identified to be unacceptably high. Therefore unit commanders need guidelines to enable an assessment of risk to be made. The identification of risk factors that apply to groups may well be used as part of the advice on the appropriate selection of activity to prevent heat illness. This is particularly the case for unacclimatised troops and for soldiers exercising in impermeable protective clothing (for Nuclear, Biological and Chemical protection). This aspect of advice also includes measures of environmental heat. The physiological limitations to this have also been discussed. However there is also the practical difficulty of choosing which measure to use and what temperature should be used to set limits. The US Forces use the limits set by Minard in the 1960s. The British Army have copied these but use limits set at the Celsius value rounded down to the nearest degree. There has not been any subsequent work to establish the validity of the limits chosen or indeed the adequacy of the WBGT Index as a measure of physiological load. These guidelines will not abolish heat illness and, indeed, heat illness has been reported by several authors to occur at temperatures within the guidelines as can be seen from Figure 2. Furthermore the risk of heat illness that was acceptable in the 1950s when these guidelines were originally written may now not be acceptable.

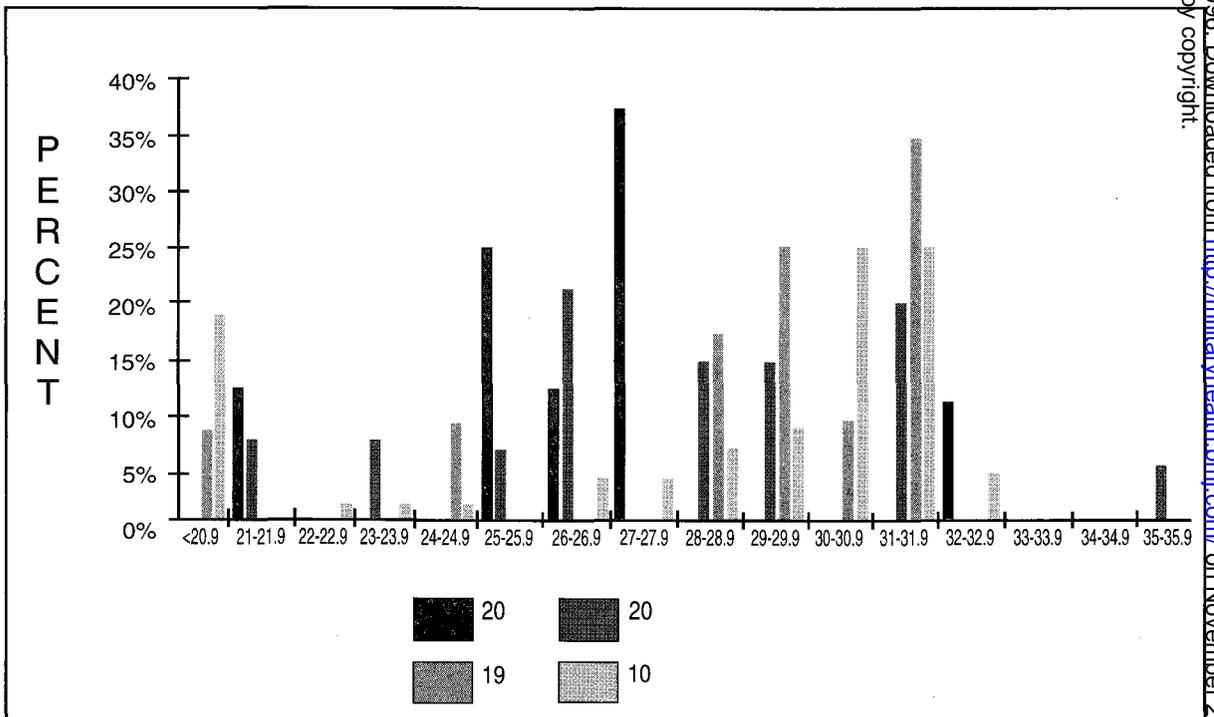


Fig 2. Percent of Reported Cases At Different WBGT

Table 8
Comparison US, British, Israeli Guidelines

	WBGT	
US Army (30)	British (7)	Israeli (21)
78°F (25.5°C) - caution as intense physical exertion may cause heatstroke		< 18°C (64.4°F) low risk 18-23°C (64.4-73.4°F) moderate risk
82°F (27.7°C) – discretion with heavy exercise for unseasoned troops	26°C (78.8°F) – discretion for unacclimatised troops	
85°F (29.4°C) – suspended for troops with less than 3 weeks acclimatisation	29°C (84.2°F) – no strenuous activity for unacclimatised personnel	23-28°C (73.4-82.4°F) high risk >28°C (>82.4°F) very high risk
88°F (31.1°C) – curtailed for troops with less than 12 weeks acclimatisation	31°C (87.8°F) – no strenuous activity for troops with less than 12 weeks acclimatisation	
90°F (32.2°C) – suspend all training	>32°C (89.6°F) – all outdoor training halted	

The Israeli Army assessment of risk from WBGT Indices is very different from the US Army guidelines. The temperature cutoffs are at a much lower level than the US Army figures. There is therefore a clear divergence of opinion on the risk/temperature balance, where the threshold limits should be and what they should represent (Table 8).

The WBGT Index has been accepted in the US and Britain as the best index of physiological heat load. However there are other indices available such as the WBT, CET, WGT (Wet Globe Temperature), P4SR (predicted 4 hour sweat rate), HSI (heat stress index) etc (31). Ideally the method chosen should be measured on equipment that is robust and easy to use. It should be possible to take measurements at or near the soldiers at risk. The current systems available measure the WBGT are either glass bulb thermometers or delicate electronic thermometers, neither of which are suitable for military field use. The Botsball (which measures WGT) may provide a solution but it has been criticised for its lack of concordance with the WBGT. However, the continued development of solid state technology may overcome this problem if the military is prepared to fund it.

The method of presentation of educational material for soldiers, unit commanders and military doctors has not been the subject of any study. Clearly the benefits of learning by personal experience are to be avoided if at all possible. To a certain degree the solutions are commonsense. All units likely to be deployed or warned

for actual deployment to a hot climate should receive instruction. All training establishments should include instruction on environmental illness as part of their syllabus. Military doctors need particular education in order that they might give authoritative advice to unit commanders. However it is not clear exactly what information should be provided and in what format. The current British instructions provide general information but do not give specific advice except for the WBGT guidelines. The American guidelines give specific instruction on water requirements and work rest cycles (Table 4). There are, as yet, no studies available to determine exactly what unit commanders would like as guidance.

Finally, no system for the prevention of heat casualties is complete without a structured surveillance system. This can provide a baseline for further changes. It enables high risk activities to be identified and would allow the guidelines for prevention to be tailored to the actual risks. Many cases occur in circumstances that might be considered avoidable in retrospect but an examination of why the activity was performed, what guidance or experience the instructor controlling the activity had available and the incidence of genuine heat intolerance are all factors that need to be examined. Heat illness in military forces will still occur: and there are many aspects of the problem that can still be researched. The resulting solutions may save even more lives.

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