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ASHCA/NIOSH CONFERENCE: PANEL PRESENTATION

Preventing Heat-Related Illness Among Agricultural Workers

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ABSTRACT. Hyperthermia from exertion and environmental conditions during agricultural work manifests itself by various symptoms and may lead to death. From 1992 through 2006, 68 workers employed in crop production and related services died from heat-related illness. The crop worker fatality rate averaged 4 heat-related deaths per one million workers per year—20 times higher than the 0.2 rate for US civilian workers overall. Many of the agricultural workers who died were foreign-born. Foreign-born workers tend to have limited English language skills and often are not acclimatized to exertion in hot weather when beginning seasonal jobs. Increased recognition of heat hazards to agricultural workers, in particular, has stimulated concern among employers, workers, and public policy makers. California and Washington have led the nation in adopting workplace safety standards designed to prevent heat-related illnesses. These state regulations include new specific requirements for employer provision of drinking water, shade for rest or other sufficient means to recover from heat, worker and supervisor training, and written heat safety plans. Agricultural employers face practical challenges in fulfilling the purpose and complying with these standards. By their very nature the standards impose generic requirements in a broad range of circumstances and may not be equally protective in all agricultural work settings. It is vital that employers and supervisors have a thorough knowledge of heat illness prevention to devise and implement safety measures that suit local conditions. Ongoing risk-based assessment of current heat conditions by employers is important to this safety effort. Workers need training to avoid heat illness and recognize the symptoms in themselves and coworkers. Innovative management practices are joining time-honored approaches to controlling heat stress and strain. Research targeted to answer questions about heat accumulation and dissipation during agricultural work and audience-sensitive education to promote understanding of basic physiology and recognition of

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hyperthermia symptoms can aid in heat illness prevention. This review was prepared for the Agricultural Safety and Health Council of America/ National Institute for Occupational Safety and Health conference, "Be Safe, Be Profitable: Protecting Workers in Agriculture," Dallas/Fort Worth, Texas, January 27–28, 2010.

KEYWORDS. Acclimatization, dehydration, exertion, fatality, heat-related illness, heat stress, hyperthermia, prevention

INTRODUCTION

Heat stress from exertion and environmental heat sources commonly results in physiological strain among workers in many occupational settings—agricultural work is a prominent example. Yet public perceptions of heat risk in the United States and Europe generally focus on mortality of the elderly, the very young, and the chronically ill during heat waves.[1–7] In the United States from 1999 through 2003, 3442 heat-related deaths were recorded (nearly 700 per year).[3] Heat exposure was indicated as the cause of death for about two thirds of the cases and as a contributing factor for the balance of the deaths. Despite broadening of the definition of heat-related mortality by the National Association of Medical Examiners in 1997, failure to identify heat-caused deaths continues.[6–8]

Likewise, occupational heat-related illnesses and fatalities are probably undercounted. From 1992–2008 the US Bureau of Labor Statistics (BLS) Census of Fatal Occupational Injuries (CFOI) indicated that 487 worker deaths, 29 per year on average, resulted from exposure to environmental heat.[9] Unlike the heat-related deaths among the general public, these deaths frequently occurred among relatively young workers.

Despite decades of physiological studies on soldiers, athletes, and civilian workers, the full magnitude or impact of nonfatal heat strain in the workplace is not known. It is clear, however, that excess heat affects cognitive and physical performance.[10–13] Heat-induced physiological changes and dehydration may influence comfort, strength, endurance, vision, coordination, concentration, and judgment such that unsafe acts, injuries, and illnesses are more likely.[10,12] This knowledge should guide measures to reduce heat illnesses in field, orchard, ranch, nursery, vineyard, dairy, and other agricultural workplaces.

EPIDEMIOLOGY OF OCCUPATIONAL HEAT-RELATED ILLNESS

In 2003 through 2008, CFOI recorded 196 deaths attributed to heat exposure out of more than 30,000 occupational fatalities across all US industries.[9] At least 40 (~7/year) of the deaths occurred in the Agriculture, Forestry, Fishing, and Hunting (Ag/For/Fis/Hun) industry sector, within which these heat deaths represented about 10% of all injury-related deaths.

Across all industries, the 196 workers who died from exposure to environmental heat were largely male (97%, 191); ranged in age from less than 20 to greater than 64, with at least 74% (≥145) younger than 55 years of age (median age in the range 35–44 years); and were predominantly white–non-Hispanic (48%, 95), Hispanic (32%, ≥63), and black–non-Hispanic (16%, 31). The construction industry had the greatest proportion of heat-related deaths (36%, 70), followed by service providing (26%, 51) and agricultural industries (20%, 40). The Ag/For/Fis/Hun sector had the highest average heat fatality *rate* (~0.3 deaths/100,000 full-time workers (FTE), compared to 0.02 for all industries) (Figure 1).[9] In 2008, there were 25.9 Ag/For/Fis/Hun deaths per 100,000 FTE from all causes.

In 1992–2006, workers in crop production and support activity industry subsectors accounted for 67% of the Ag/For/Fis/Hun sector heat-related deaths and 16% of all heat-related death (Table 1).[14] At least 55% of the

FIGURE 1. Rate of occupational fatalities by industry sector for exposures to environmental heat in the United States, 2003–2008. Data from the BLS Census of Fatal Occupational Injuries (CFOI).[9] Data for 2008 are preliminary. †Rate = deaths per 100,000 full-time equivalent workers; 1 full-time equivalent = 2000 hours worked/yr; rate denominators were derived from the Current Population Survey for primary job of workers aged ≥16 years. §Ag/For/Fis/Hun = North American Industry Classification System Sector 11—Agriculture, Forestry, Fishing, and Hunting. ¶Deaths for Ag/Forest/Fish in 2004 and 2007 did not meet the minimum CFOI reporting requirements; therefore the rates were set to zero.

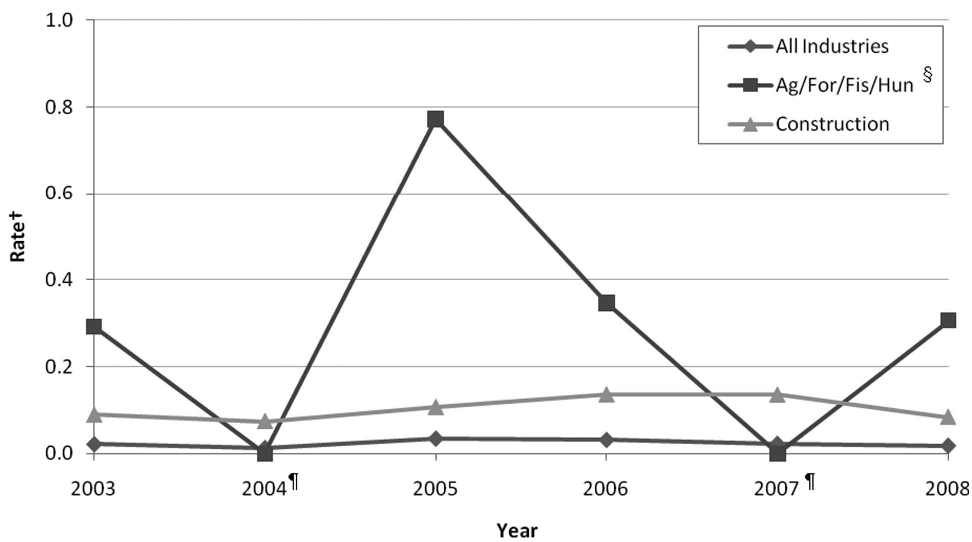


TABLE 1. Number and Average Annualized Rate of Occupational Heat-Related Deaths Among Crop Workers, United States, 1992–2006[14]

	Number of deaths	Rate (deaths/100,000 FTE*)
Industry sector/subsectors		
All industries	423	0.02
Ag/For/Fis/Hun	102	0.16
Crop production and support activities	68	0.39
Crop production and support activities (crop workers)		
Crop production	52	0.36
Vegetable and melon	15	—
Fruit and tree nut	11	—
Other crops	19	—
Other/unspecified	7	—
Support activities	16	0.59
State of injury (crop workers)		
California	20	0.49
Florida	6	0.74
North Carolina	13	2.36
Other states	29	—

*FTE = full-time equivalent worker based on 2000 hours worked per year.

crop workers were born outside the United States, most in Central and South America. Most of the crop worker deaths were in July (59%), and most incidents occurred after 1 pm (68%). Twenty-one states reported heat-related crop worker deaths during the 15-year period, but California, Florida, and North Carolina accounted for 57% of the deaths (Table 1). North Carolina's particularly high rate may result from many factors, such as rates based on small numbers, potential climatic differences, and/or types of crops harvested. Exposure to nicotine during tobacco harvesting in North Carolina may have exacerbated the heat strain effects.[14–16]

In contrast to fatalities, the prevalence of nonfatal heat-related illnesses among workers nationally is essentially unknown. The BLS Survey of Occupational Injuries and Illnesses (SOII) collects data on Occupational Safety and Health Administration (OSHA) recordable cases from primarily private industry employers (excluding farms with less than 11 employees). Heat-related illnesses are within the SOII scope, but only cases resulting in one or more days of lost work-time are specifically enumerated. From 2003 to 2008 there was an average of 2260 heat-related illnesses/year that resulted in one or more days away from work.[9] Within the Ag/For/Fis/Hun sector the average was only 55 cases/year. This low level of reported nonfatal heat illness cases is not surprising. Most workers with any heat-related illness short of severe exhaustion likely self-treat, do not report to their supervisor/employer, and do not take time off to recuperate.

On a state basis, the Washington Department of Labor and Industries (WA L&I) examined workers' compensation data for 1995–2005.[17] The Ag/For/Fis/Hun sector had the third highest heat-related claims rate, 5.2 claims per 100,000 FTE. Duration of employment was reported for about two thirds of claims across all industries. Among these cases, 14% of the claimants were in their first week of work, suggesting that lack of physiological acclimatization may have played a role. Moreover, about one fifth of all claims indicated that medication or an existing medical condition may have contributed to the heat-related illness.

In California, the Division of Occupational Safety and Health (Cal/OSHA) investigated numerous reports of heat-related illness largely in construction and agriculture.[18,19] In 2005, 54% of the cases involved a heat-related death and 38% involved hospitalization of a worker who survived. All victims were male; most worked outside (84%); and a majority spoke Spanish as their primary language (68%). Forty-six percent of the affected workers were on their first day on the job, 80% within their first 4 days, suggesting that they were not yet acclimatized to exertion in hot weather. In 2006, 46 cases of heat-related illness were investigated. Most of the illnesses occurred during a 13-day heat wave, with many of the workers having been on the job for more than a week.[6,19] During the heat wave, night time temperatures remained high, potentially impacting workers' recovery from the prior day's heat strain. Furthermore, despite having worked in hot conditions, they may not have been adequately acclimatized to the significantly higher temperature.[19,20]

From 1977 through 2001, 40 of 161 heat-related deaths in North Carolina were attributed to work.[21] Forty-five percent of the occupational deaths occurred among agricultural workers. Reports of more recent crop worker deaths in North Carolina highlight the etiology of these types of deaths (e.g., Table 2).[14,22] The findings indicated the importance of recognizing serious heat-illness symptoms, getting prompt medical care, and assessing adequacy of acclimatization.

The limited data available show markedly higher heat-related death rates in Ag/For/Fis/Hun than in other sectors. The extent to which difficulties and inconsistencies inherent in identifying heat-related deaths contribute to underestimation of heat-related illnesses in agricultural work is not clear. The paucity of data on nonfatal heat illnesses and heat effects on productivity and susceptibility to other injuries impedes efforts to introduce and assess various risk reducing interventions.

TABLE 2. Etiology of a Crop Worker Death[14]

Environmental conditions	Worker characteristics	Approximate timeline*	
North Carolina	Male, 56 years of age	6:00 AM	Started work
Mid-July	Hispanic ethnicity	9:00 AM	Mid-morning break
Local high temp. ~93°F	Spanish speaking (only)	11:30 AM	90-min lunch
Humidity ~44%	In US on H-2A visa for contract work	2:45 PM	Observed working slowly; employer instructed him to rest, but he continued working
Clear skies	Hand harvesting tobacco	3:30 PM	Coworkers noticed that he appeared confused. Although combative, coworkers carried him to the shade and tried to give him water (unsuccessfully)
Heat index†	4th day in US		
Mid-morning: 86–101°F	3rd day at work		
Mid-afternoon: 97–112°F			
Similar conditions for preceding 2 days	Trained on pesticide hazards	3:50 PM	Coworkers notified employer
		4:25 PM	Taken by ambulance to ED; core temp = 108°F. Worker succumbed to heat stroke
	Not trained on heat hazards		

*Times are approximate based on employer and coworker information.
†Lower value represents reported heat index for the area. Range of +15° shown because of potential influence of local conditions (e.g., clear skies).[23]

HEAT STRESS, STRAIN, AND ILLNESS

Heat Stress and Strain

Exposure to excess heat from a person's own metabolism and/or from sources in the environment is termed *heat stress*.[20] The physiological response to dissipate heat and maintain a core body temperature of 98.6°F (37°C) is referred to as *heat strain*.[20] Environmental heat especially affects the general public during hot weather periods. However, metabolic heat produced through farm work is a significant burden that can cause heat strain among workers in much cooler weather. The American Conference of Governmental Industrial Hygienists (ACGIH) developed methodology for assessing heat illness risk by using wet bulb globe temperatures (WBGTs) in combination with workload estimates.[20]

When a high rate of exertional heat production combines with harsh environmental conditions, heat stress and the potential for developing heat illness increase considerably. Environmental factors such as ambient temperature, humidity, air movement, confined space ventilation, clothing worn, surface reflection and absorption, and direct sun exposure all influence the heat load on a worker. [20,23–26] Many of these factors directly or indirectly act as modifiers of heat transfer from the body to the environment rather than as sources of heat.

The US Army identified six primary "agents" of heat stress: ambient air temperature; wind velocity; relative humidity; mean radiant temperature; metabolic heat production; and clothing insulation.[27] The latter two agents, driven by demands of the operation, are deemed to have the most impact on heat effects in military operations. Likewise in agriculture, exertional heat generation and choice of clothing to meet the requirements and employment conditions of a farm job significantly influence heat stress.

Human thermoregulatory responses to heat stress include heart rate elevation, vasodilation, increased circulation to the skin, and sweating to generate heat transfer and evaporative cooling at the skin surface.[24,28,29] With continued heat strain, the shift in blood flow compromises internal organs and prolonged sweating depletes plasma volume and electrolytes, resulting in observable heat illness symptoms. Progressive dehydration impairs and may overwhelm the thermoregulatory processes, allowing core body temperature to rise and threatening the cardiovascular and central nervous systems. As the core body temperature reaches 104°F, organ failure and death are likely if cooling of the individual and medical care are not immediately obtained.

The amount of metabolic heat generated by physical activity and the body's ability to dissipate heat vary by individual factors such as age, sex, fitness, heat acclimatization, acute and chronic health conditions, medications, obesity, degree of hydration, and electrolyte balance.[20,25,26] For a sedentary population, the National Weather Service's Heat Index is fairly representative of the environmental heat stress. The Heat Index is an exposure metric based on air temperature and humidity, assuming shady, light breeze conditions. Direct sun exposure increases the index by up to 15°F.[23] Because this index does not take metabolic or radiant heat into account, it should not be the sole reference in assessing heat risks for workers. However, the heat index can play a role as a part of an alert system for daily conditions and for forthcoming heat waves that may significantly affect workers.[26]

Various thermal stress indices that consider metabolic heat have been developed.[20,30,31] The ACGIH has produced a Threshold Limit Value (TLV) for heat stress to maintain the core body temperature at ≤38°C (100.4°F). The ACGIH method uses WBGTs with adjustments for metabolic rate, clothing requirements, and work-rest cycles as a screening tool to evaluate the potential for adverse heat stress. For example, going from rest to moderate work activity increases the metabolic rate nearly 200% and effectively reduces the TLV from ~34°C (93.2°F) to 28°C (82.4°F). Clothing choices generally impact heat stress to some degree, but vapor barrier coveralls are so insulating that they can raise the effective WGBT by 11°C (~20°F). Work-rest cycle adjustments that extend time for physiological recovery are critical to compensate for the increased heat stress. The heat stress indices generally assume that workers are heat acclimatized. Understanding attributes of workers more prone to heat strain and monitoring all workers for symptoms will aid risk assessments. Noninvasive monitoring of degree of sweating, heart rate, and oral temperature can provide early warning of heat strain symptoms.[20,26]

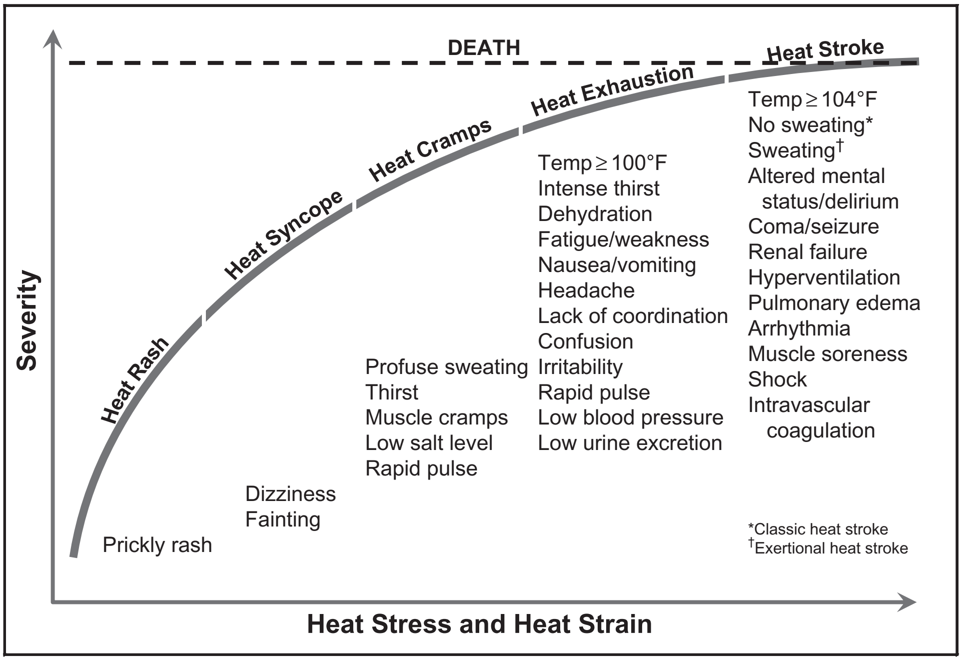
Heat-Related Illnesses

Heat stress may cause mild discomfort to death. Sets of symptoms caused by excess heat and the body's autonomic dissipation mechanisms are commonly categorized as one of five illnesses: heat rash, heat syncope, heat cramps, heat exhaustion, and heat stroke (Figure 2). Although symptomatically differentiated, these diagnosable illnesses arise from increasingly serious effects from the same heat stress and strain phenomena. Individuals may or may not manifest symptoms of the less serious heat illnesses before experiencing heat exhaustion or stroke.

Despite individual differences, workers of all ages are particularly susceptible to heat strain when laboring in hot conditions. Heat rash is an irritating skin inflammation from clogged sweat glands. Heat syncope is a temporary loss of consciousness due to insufficient blood and oxygen to the brain. It most often afflicts people not acclimatized to exertion in a hot environment, such as at the beginning of a season; start of a new job; or after a sudden heat increase. Heat cramps are painful muscle contractions generally induced by an electrolyte imbalance after intense sweating. Heat exhaustion may present as muscle weakness, fatigue, and a host of other symptoms during strenuous work in a hot environment after dehydration reduces blood volume and circulation. Heat stroke is the frequently fatal result of complete breakdown of the body's thermoregulation ability. Nonfatal heat stroke cases may require extended recovery periods and result in permanent organ damage.

Heat illness symptoms are similar to many symptoms of pesticide poisoning and green tobacco illness (nicotine poisoning)[15,16,32] as well as other common virus or gastrointestinal illnesses. Nonetheless, signs suggesting heat exhaustion or stroke should prompt immediate medical attention, particularly in field conditions. Heat exhaustion may progress rapidly to stroke if not treated.

FIGURE 2. Simplified model of heat-related illness conditions with associated symptoms.[20,23–25,46] The heat illness conditions are not a physiological continuum such that individuals may not incur all conditions. Symptoms may vary by individual, heat illness condition, and time since onset. Some symptoms may be present in multiple conditions.



PREVENTING HEAT-RELATED ILLNESS

Extensive heat stress studies in athletic[33,34] and military settings[27] provide guidance applicable to agricultural workplaces. Three essential strategies for minimizing harm from hyperthermia are (1) reduce the body's heat gain, (2) facilitate heat release, and (3) compensate for fluid and function losses in the body's autonomic response to heat stress—that is, replenish water lost as sweat and respond to early stage heat strain symptoms.

The nature and conditions of agricultural jobs typically constrain workers' ability to follow some recommendations for maintaining a healthy balance of heat gain and loss, such as avoiding sun exposure, and reducing exertion level while increasing rest breaks in hot weather. Much of the work is physically demanding, during warm months, and driven by crop maturation and market forces. Moreover, output-based pay for self-paced tasks often elicits high levels of exertion.

Farm managers who understand the physiological impacts of heat can help workers reduce heat gain and facilitate heat release through administrative and engineering means, such as

- Educating field supervisors and workers about heat strain physiology, symptom recognition, and when prompt medical treatment is needed
- Monitoring environmental conditions through the use of heat stress indices (e.g., using WBGT), providing heat alerts, and modifying tasks and performance standards based on local conditions
- Adjusting rest period frequency and length in accord with heat stress indices
- Modifying tools, equipment, or processes to reduce physical demands on workers

- Designing work assignments to mix heavy and light work in a cycle
- Identifying nonacclimatized workers and assigning them less strenuous tasks with gradually increasing workloads
- Scheduling more strenuous jobs for cooler hours
- Furnishing shaded work and/or rest stations accessible to all heat stress–exposed workers
- Climate-controlling machine operator cabs
- Supplying misters, fans, or other devices that aid cooling
- Providing water and "sports drinks" and encouraging frequent consumption
- Establishing emergency plans for prompt medical treatment

Drinking early and often, not simply in response to thirst, is generally regarded as crucial to controlling heat stress. It is the employer's responsibility to encourage workers to drink sufficiently to maintain hydration, to ensure water availability, to facilitate worker access, to provide regular rest breaks of appropriate duration for the work conditions, and to monitor workers for signs of heat illness. Workers can help themselves by drinking and eating regularly to replace lost fluids and electrolytes and wearing light colored clothing as well as monitoring themselves and coworkers for heat strain symptoms. Symptomatic workers should get immediate help from the field supervisor or coworkers. Unfortunately, in the later stages of heat illness, a worker may lose all ability to self-help. Surrounding workers with managers and coworkers knowledgeable about heat stress supports a community approach to preventing heat illnesses.

Heat Illness Awareness and Training

Effective prevention efforts begin with an employer recognizing the seriousness of heat stress risks. Managers can convey concern and education about heat as a safety issue through planned training sessions, periodic alerts, casual conversation, structural adjustments, and personal example. Training that is engaging, in a comfortable setting, and free of earnings-opportunity costs is most likely to enable and encourage workers to follow safe practices. Effective training should be based on sound health communication principles,[35] conducted in the workers' primary language, and appropriate for local conditions. Important basics to cover include how the body reacts to heat, what the signs and symptoms of heat illness are, and how to reduce the influence of heat through hydration, cooling off, and rest, as well as how to respond if a heat illness occurs. Federal OSHA,[36] labor departments in California,[37] Washington,[38] and North Carolina,[39] various educational institutions,[40–43] and other entities provide numerous, often multilingual, heat illness prevention resources.

Acclimatization

Heat acclimatization is a temporary physiological adaptation that improves tolerance and dissipation of heat. Individuals who exert themselves in hot weather for at least 2 hours per day tend to adapt over 4 to 14 days.[20,26,28,32,44–46] Most importantly, sweating begins earlier, in greater volume, and with less loss of electrolytes. These adaptations reverse after work in hot conditions ceases. Significant decreases can occur in days. Dry-heat–adapted and more physically fit workers tend to retain their acclimation better than humid-heat–adapted or less fit individuals.[28]

Case reports and workers' compensation claims for heat-related illnesses and fatalities often highlight a lack of acclimatization as indicated by workers becoming ill in their first few days on the job.[14,17–19,22,32] In California, initial acclimatization was suggested to not suffice if temperatures rise.[19,20] Similarly, after a 1- to 2-week absence, previously acclimated workers who return to work in the heat need reacclimatization. Thus, employers need to plan for acclimatizing new and returning workers as well as all workers at the beginning of a heat wave. Integrating a gradually increasing workload into an initial week of light, low-heat-stress activity is recommended to avoid heat-related illness among unacclimatized workers. For partially acclimatized workers, increasing rest period frequency throughout the day, such as at the beginning of a heat wave, may be effective.

Although heat acclimatization commonly refers to physiological adaptations, workers experienced with laboring in hot environments may also make behavioral adaptations such as drinking more frequently, taking better advantage of rest breaks, carefully pacing their effort, and making other personal or task modifications that reduce heat stress. Effective behavioral adaptations should be included in training for new workers.

Hydration

To maintain a level of hydration supporting good health and performance, workers must replenish fluids (and electrolytes) lost primarily through sweating and urination. Sweat loss can exceed 2 quarts/hour.[11,47,48] Electrolyte loss (e.g., sodium), which can be significant when exposed to high-heat-stress conditions, also plays a crucial role in heat strain pathophysiology.[47] General occupational guidance indicates that workers should drink about 1 cup of water per 20 minutes,[20] but individual and situational needs for fluid replenishment vary considerably. The military has developed hydration and work-rest guidance[49,50] (Figure 3) that may be more appropriate for agricultural field workers than historical occupational guidance.[10] The military guidance is designed to maintain hydration, but limits water intake to 1.5 quart/hour to minimize hyponatremia effects on electrolyte balance. Others have suggested that replenishment of up to150% of fluid lost is safe as long as the rehydration fluid contains enough sodium to avoid hyponatremia.[51]

Maintaining electrolyte balance is best done through normal food intake, which also encourages water consumption.[10] However, numerous studies have examined the use of electrolyte and carbohydrate enhanced drinks (e.g., sports drinks).[28,48,52,53] Although equivocal, the results suggest that there are some benefits from drinking appropriately balanced electrolyte solutions that are relatively low in carbohydrates. In general, evidence is insufficient to support requiring agricultural employers to provide such drinks or to prohibit their use on an individual basis. Historically, caffeinated beverages have been contraindicated before or during heat stress exposure because of their diuretic effects. Recent research on hydration influences of these drinks has found minimal influences beyond the first few hours after ingestion, particularly for regular consumers of caffeinated beverages.[53–55]

Consensus recommendations on what to drink, how much, and how often are not easily translated to field conditions; may not appropriately take into account workloads; and usually

FIGURE 3. US army work/rest and water consumption table and urine color test card.[50,60]

Work/Rest and Water Consumption Table

Applies to average sized, heat-acclimated soldier wearing BDU, hot weather. (See TB MED 507 for further guidance.)

Easy Work	Moderate Work	Hard Work
• Weapon Maintenance • Walking Hard Surface at 2.5 mph, < 30 lb Load • Marksmanship Training • Drill and Ceremony • Manual of Arms	• Walking Loose Sand at 2.5 mph, No Load • Walking Hard Surface at 3.5 mph, < 40 lb Load • Calisthenics • Patrolling • Individual Movement Techniques, i.e., Low Crawl or High Crawl • Defensive Position Construction	• Walking Hard Surface at 3.5 mph, ≥ 40 lb Load • Walking Loose Sand at 2.5 mph with Load • Field Assaults

Heat Category	WBGT Index, F°	Easy Work		Moderate Work		Hard Work	
		Work/Rest (min)	*Water Intake (qt/hr)*	*Work/Rest (min)*	*Water Intake (qt/hr)*	*Work/Rest (min)*	*Water Intake (qt/hr)*
1	78° - 81.9°	NL	½	NL	¾	40/20 min	¾
2 (GREEN)	82° - 84.9°	NL	½	50/10 min	¾	30/30 min	1
3 (YELLOW)	85° - 87.9°	NL	¾	40/20 min	¾	30/30 min	1
4 (RED)	88° - 89.9°	NL	¾	30/30 min	¾	20/40 min	1
5 (BLACK)	> 90°	50/10 min	1	20/40 min	1	10/50 min	1

- The work/rest times and fluid replacement volumes will sustain performance and hydration for at least 4 hrs of work in the specified heat category. Fluid needs can vary based on individual differences (± ¼ qt/hr) and exposure to full sun or full shade (± ¼ qt/hr).
- **NL** = no limit to work time per hr.
- **Rest** = minimal physical activity (sitting or standing) accomplished in shade if possible.
- ***CAUTION: Hourly fluid intake should not exceed 1½ qts.***

  Daily fluid intake should not exceed 12 qts.
- If wearing body armor, add **5°F** to WBGT index in humid climates.
- If doing Easy Work and wearing NBC (MOPP 4) clothing, add **10°F** to WBGT index.
- If doing Moderate or Hard Work and wearing NBC (MOPP 4) clothing, add **20°F** to WBGT index.

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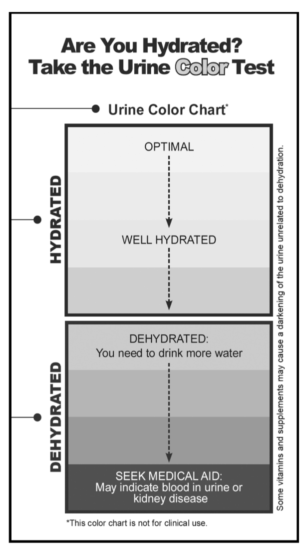

do not include recommendations on consumption before or after work.[10] A general presumption that workers begin their shift in a well-hydrated status often does not hold true for a variety of reasons, including insufficient rehydration from the prior day's work, illness, and medications.[56,57]

Individual worker and field or situational factors strongly affect what workers do to stay hydrated. Simply providing adequate quantities of potable water is insufficient to insure hydration. Workers who have been trained about the importance of hydration appear to drink more frequently and better avoid "voluntary" dehydration.[57] Workers generally prefer cool, palatable water with individual preferences to flavoring and other beverages despite some laboratory research indicating adequacy of ambient-temperature water.[58] Because workers experience "costs" of access to drinking water in the form of foregone piece-work earnings, supervisory or coworker disdain, personal embarrassment, and physical effort to cover long distances, placing and keeping containers close to the work activity encourages greater consumption.[41] Hands-free personal water containers have been shown to facilitate drinking by workers wearing respirators or vapor-barrier clothing.[59] Women workers have been noted to avoid drinking when bathrooms are not readily available.[10]

Measuring hydration status in field situations is difficult, but workers can use a simple urine-color chart such as developed by the military[60] (Figure 3) to roughly monitor themselves. Overall, in field settings, heat strain may be monitored best by observation of resting heart rate[20] and heat illness symptoms. With the aid of their employers, workers could measure their weight before and after each shift.[10] A weight loss of more than 1% suggests a functional hydration deficit[10] and a loss of several percent should prompt close monitoring. Although noninvasive, weight-monitoring programs are unlikely to be adopted in most farm settings.

Reducing Heat Stress and Strain

Production of exertional heat can be slowed, absorption of environmental heat reduced, and dissipation of heat from the body accelerated by deliberate actions of employers and workers. Resting from strenuous work greatly diminishes metabolism and allows the body to release heat through "passive cooling." Resting or working under shade reduces direct heat gain from solar radiation and improves the thermal gradient between the body and environment. Particularly in dry climates, fans provide some heat stress relief by increasing convective and evaporative cooling, but at high heat indices and in humid climates fans are not effective at significantly reducing heat stress.[2,61] However, a fan-mister can provide effective cooling under moderate humidity conditions (i.e., 50%).[62] Partial day, air conditioning cools the body more effectively and has been shown to be beneficial in nonworkers.[61]

Light colored, single layer clothing, wide-brimmed hats, and long sleeves that help reduce heat stress also provide ultraviolet (UV) protection. Cultural preferences and cost considerations keep many agricultural workers from wearing the optimal apparel. When a job requires that workers wear multilayer or vapor barrier clothing or other personal protective equipment, employers need to be especially alert to the significant increase in heat stress produced.

Numerous devices to assist the body in reducing core temperature have been developed such as cooling vests, suits, and portable systems, as well as simple kerchiefs, bandanas, and hat liners with endothermic properties.[63–65] Two approaches to cooling that rely on the heat transfer properties of vascular structures at body extremities hold promise for adoption in agriculture. Submersion of hands and forearms in cool water significantly enhanced cooling among firefighters.[62] Similarly, heat dissipation with a commercial cooling glove was shown to be effective among athletes.[66]

In combination with hydration and cooling efforts, designated work-rest cycles tailored to the current heat stress conditions are considered necessary to prevent heat illness. Effective work-rest scheduling must account for acclimatization of the workers, activity level, and heat stress conditions. Guidance on cycle structure has been provided by the Environmental Protection

Agency (EPA),[32] the National Institute for Occupational Safety and Health (NIOSH),[26] the ACGIH,[20] and the military[50] (e.g., Figure 3). In high-heat-stress conditions rest time may exceed work time. Although increased rest time degrades apparent productivity, the performance improvements achieved by avoiding heat strain problems may significantly outweigh the loss of work time.[10] Work-rest cycles should be integrated in to heat illness prevention programs.

Regulatory Standards

Currently no federal occupational safety regulations specifically address heat illness prevention. In August 2005 California adopted an emergency heat protection standard—the first in the nation—followed by a permanent standard in July 2006.[67] Washington followed suit issuing emergency heat illness prevention regulations in 2006 and 2007 and a permanent rule in 2008.[68,69] Both state standards require employers to train supervisors and workers, to provide ready access to water and means to cool, and to establish written plans for controlling risks and responding to symptoms (Table 3).

Notable differences between the California and Washington regulations pertain to scope and cooling requirements. Whereas the California rule applies to all outdoor work year round, the Washington regulations apply only to outdoor work from May through September when the temperature meets or exceeds one of three clothing-specific temperatures. For example, the regulation applies when the ambient temperature reaches 89°F or above regardless of clothing, but at 52°F when workers wear nonbreathing or vapor barrier clothing. The Washington standard thus explicitly recognizes the significance of insulation on the rate of endogenous heat release. The Washington regulations do not specifically require provision of shade as in California, but the regulations require that workers showing signs of heat illness be relieved of duty, "provided with sufficient means to reduce body temperature," and monitored. Also unlike the California rule, the Washington standard assigns employees the responsibility to monitor their personal risk factors and hydration status. The text of the regulations and state enforcement guidance offer more detail and interpretation.[67–71]

PREVENTION EFFORTS IN THE AGRICULTURAL INDUSTRY

Agricultural employers throughout the nation have taken various measures to prevent heat illness. Aggressively enforced heat illness prevention regulations in California and Washington have increased recognition of and motivation to alleviate heat hazards. Training regulations have spawned production of numerous public as well as commercial training programs and aids. Employers have implemented training programs attuned to the race, ethnicity, and first language of workers they employ.

Various improvements in access to water have been implemented from moving the water station as workers progress through a field, to adding water containers directly to farm machinery or an in-field work station, to providing personal hands-free hydration devices. Shade requirements have been met naturally and artificially (Figure 4). Trailers have been adapted to combine portable shade and seating with drinking water and toilet facilities. Although not required, awnings fitted on many field harvest machines provide shade to work stations that move along with the workers and that include water and bathroom access.

In some situations, heat stress has been alleviated through use of mechanical aids that reduce task strenuousness, scheduling work at night, and job redesign. For example, machinery that moves harvested crops within a field or that elevates multiple workers to orchard picking height relieves burdens of carrying and climbing that would require greater exertion (Figure 5). Having a worker harvest and package a product in a shaded environment provides a reduction in both exertional and environmental heat stress through the mixing of heavy and light duty activities. Likewise, frequent alternating of two worker teams with heavy- and light-duty activities or with work-rest cycles can significantly reduce heat stress while maintaining production flow.

Despite the responsible and innovative ways that many agricultural employers are addressing

TABLE 3. Comparative Synopsis of California and Washington Heat Illness Prevention Requirements*

Characteristic	California†	Washington‡
Scope	Applies to all outdoor places of employment	Applies to all outdoor work from May 1 through September 30 when employees are exposed to heat at or above specified clothing-dependent temperatures Nonbreathing clothes 52° Double-layer clothes 77° All other clothing 89°
Hydration	Access to potable water At least 1 qt/worker/h must be available for the duration of the shift Encourage frequent drinking	Access to cool potable water At least 1 qt/worker/h must be available for the duration of the shift Employees are responsible for monitoring their own consumption of water or other acceptable beverage to ensure hydration
Cooling and response to symptoms	Access to shade for at least 5 min for employees suffering from heat illness or believing a recovery period is needed to prevent onset Nonagricultural employers may provide alternative cooling in lieu of shade	Relief from duty, a sufficient means to reduce body temperature, and subsequent monitoring for employees showing signs of heat stress
Training	Employee training topics Environment and personal risk factors for heat illness Employer's procedures for complying with the standard Importance of frequent consumption of water; up to 4 cups/hour Importance of acclimatization Different types of heat illnesses and symptoms Importance of immediately reporting to supervisor heat illness symptoms in themselves or coworkers Employer's procedures for responding to heat illness symptoms including emergency medical services Employer's procedures for contacting EMS or transporting workers Employer's procedures for ensuring that clear directions to worksite are provided to emergency responders	Employee training topics Environmental heat factors Personal factors that increase susceptibility to heat illness Importance of removing heat retaining PPE during breaks Importance of frequent drinking Importance of acclimatization Types and symptoms of heat illnesses Importance of immediate reporting of heat illness symptoms and procedures for emergency aid
	Supervisor training topics All employee topics Procedures for supervisor to follow to implement heat illness prevention Procedures for supervisor to follow when worker exhibits symptoms or requires emergency response	Supervisor training topics All employee topics Procedures for supervisors to implement heat program Procedures for supervisors to aid workers with symptoms and to get EMS Procedures for moving employee to a place where EMS can reach them
Program documentation	Written procedures available to workers and inspectors	Must include outdoor heat safety program in written accident prevention program

*This table presents general information about the standards. See the specific regulations and the enforcement guidance for detailed provisions and interpretations.
†California Code of Regulations, Title 8, Section 3395 Heat Illness Prevention.[67]
‡Washington Administrative Codes 296-62-095 and 296-307-097 Outdoor Heat Exposure.[68,69]

FIGURE 4. Examples of shade in California field settings. (photos courtesy of Howard Rosenberg.)

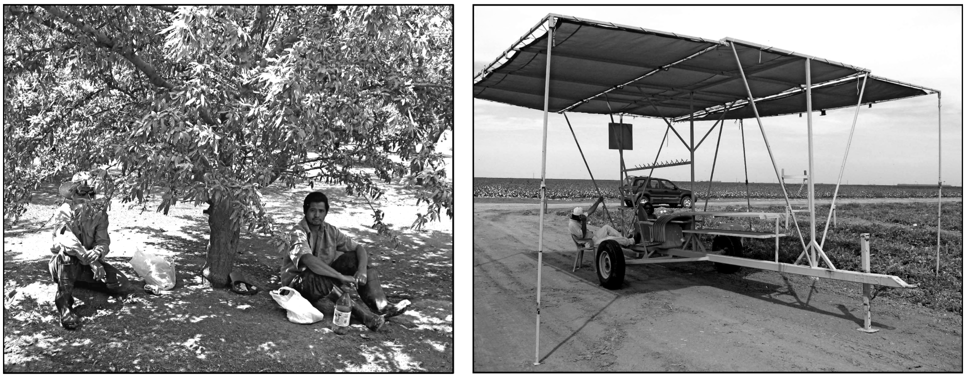

FIGURE 5. Harvesting machinery can reduce exertional heat stress and provide ready access to shade and water. (photos courtesy of Howard Rosenberg.)

heat illness prevention, numerous employers have not implemented adequate prevention programs. In 2008–2009, California conducted over 6000 site inspections across all industries. Twenty-eight percent of the inspections resulted in one or more heat exposure citations (personal communication, Cal/OSHA, 2010). Also in 2008–2009, in Washington where the outdoor heat exposure season is only 5 months long, nearly 1500 site inspections were conducted and 76% of the inspections resulted in a citation (personal communication, WA L&I, 2010). Reviewing state OSHA enforcement guidance and taking advantage of state consultation services can help employers improve effectiveness and compliance of their heat safety programs.

FUTURE DIRECTIONS

Effective company-wide educational efforts on the contributors to heat stress and the physiology of heat strain will provide a strong foundation for heat-illness prevention in an agricultural business. Health communications research is needed to evaluate effectiveness of different options with respect to the content, format, duration, frequency, pedagogy, and context of instruction for managers, field supervisors, and workers with various cultural and educational backgrounds. Studies to reveal current, often culturally grounded, beliefs that may conflict with accepted scientific principles or thwart implementation of risk reduction measures would be valuable.

Important questions about heat production, cooling, and impacts in a variety of agricultural settings remain unanswered. We need to know more about (1) the heat load generated by performance of specific agricultural jobs under a range of conditions; (2) effects of various work/rest patterns and cooling aids (not limited to shade) on perceived exertion, core temperature, heat dissipation rate, and productivity for various agricultural jobs; and (3) workers' behavioral responses to training and to adjustments in provision of water and other beverages. Research in these areas could inform not only employer and worker decisions but also heat-illness regulations.

The California and Washington regulatory requirements for availability of 1 quart of water per hour per worker should provide for adequate hydration under many circumstances. However, because much of what we know about hydration needs comes from laboratory studies in sports and military medicine, previous findings about what, when, and how much to drink may not provide optimal guidance for agricultural workers. Farm field studies would be useful to develop agriculture-specific recommendations about water temperature, enhanced beverages, electrolyte balance, and other aspects of hydration maintenance.

Aids to help field supervisors and workers assess heat stress conditions and individual heat strain status should be deployed more routinely in the field. Large-face thermometers, military style flag systems that indicate current conditions, and portable heat stress index systems could be applied at relatively low cost.[50,72] Simple, noninvasive procedures or tools for monitoring heart rate, estimating core body temperature, and assessing hydration sufficiency (e.g., urine-color charts) are needed.

To prevent heat illnesses in agricultural settings, a culture of heat awareness; safe work practices developed through industry specific research; and an environment where employers, managers, and workers exercise joint responsibility for preventing heat-related illnesses are needed.

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