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Working in Hot Conditions—A Study of Electrical Utility Workers in the Northern Territory of Australia

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Environmental conditions of Australia's Northern Territory are seasonally conducive to excessive body heat storage by outdoor workers. For electrical utility workers who periodically work at height, in confined space, and in proximity to live power sources, the impact of the climate may be considered a hazardous condition. Therefore, this study examined the physiological and fluid balance responses of 20 power network workers (31.5 years; 86.0 kg; 1.71 m; BMI 29.5) throughout work shifts in the Northern and Southern regions of the Northern Territory, Australia.

Twenty male heat-acclimatized power network workers provided written informed consent to be monitored during maintenance of electrical infrastructure that included replacing power pole components and transformer and substation repairs in the Northern ($n = 13$) and Southern regions ($n = 7$) of the Northern Territory (mean wet-bulb globe temperatures of 32.0°C and 28.7°C, respectively). An ingestible telemetry pill provided measurement of gastrointestinal temperature (T_{gi}), that when combined with heart rate values, provided physiological strain index (PSI). Urine specific gravity, sweat rate, and level of dehydration were also determined.

The T_{gi} values of this study were within the ISO9886 limit for monitored, heat-acclimatized workers, with a peak of 38.4°C. Mean PSI was 2.6, which represents overall low strain, with periods of moderate strain. Urinary analysis indicated that workers were dehydrated prior to and following the work shift, however the mean sweat rate of 0.44 $L.h^{-1}$ was matched by fluid consumption of 0.42 $L.h^{-1}$ to limit body mass loss to 0.1% during the shift.

This study demonstrates that heat acclimatized electrical utility workers adhere to ISO9886 requirements when undertaking self-paced activity in hot conditions.

Keywords electrical, heat stress, hydration, occupational, physiology, thermal, utility

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INTRODUCTION

Australia's Northern Territory (NT) covers ~1.35 million square kilometers that can be broadly categorized into Northern and Southern regions. The Northern region, home to the capital and most populous city, Darwin, is classified as tropical with two distinct seasons, the dry and wet. The dry season typically produces warm to hot ambient temperatures (27–32°C) with low to moderate relative humidity (<40%), while the wet season is characterized by hot ambient temperatures (30–34°C) and high levels of relative humidity (>60%). In contrast, the Southern region is less tropical, with a transition from two to four annual seasons as latitude increases. The summer months are very hot with periods of extreme conditions (>40°C), although the low relative humidity (<30%) levels render this a dry heat. The harsh conditions experienced during the Southern region summer and Northern region wet season pose a significant challenge to thermoregulation of outdoor workers. Despite an occupational heat stroke fatality during the past decade,(1) there is a paucity of literature documenting the impact of heat stress on worker health in the NT. There are however, anecdotal reports of worker heat stress episodes across a variety of industries, including electrical utilities, where workers establish and maintain electrical infrastructure, periodically requiring work at height, in confined space, and in proximity to live power sources.

Such reports are likely to become more frequent as the trend for a warming environment, commonly known as climate change, is predicted to adversely impact the outdoor working conditions of the NT. A recent report predicts the number of days where ambient temperature exceeds 35°C in Darwin to increase from the 9 days of 2008, to 221 and 312 days by 2070 and 2100, respectively.(2) Furthermore, heat stress-related labor losses are expected to double by 2050, with Australia to be among the worst hit continents.(3) The harsh outdoor environments currently experienced in the NT, combined with the predicted worsening of conditions renders strenuous physical activity as a major seasonal risk for exertional heat illness. Management of outdoor staff will therefore

TABLE I. Participant Characteristics of the NR and SR Cohorts

Cohort	n	Age (years)	Height (m)	Body Mass (kg)	Body Mass Index ($kg.m^{-2}$)
Northern region	13	34.6(11.2)	1.70(0.09)	91.4(15.5)	31.6(5.5)
Southern region	7	25.6(2.4)	1.73(0.04)	76.2(6.3)	25.6(2.6)
Combined	20	31.5(10.0)	1.71(0.08)	86.0(14.8)	29.5(5.5)

Note: Data are mean (SD).

require a thorough understanding of physiological responses to the tasks undertaken, and evidence-based strategies to limit the impact of the hot climate on employee health. Therefore, the purpose of this study was to assess the physiological responses of electric power network field service workers during the hottest seasons in the Northern and Southern regions of the NT, thus providing preliminary data from which to develop measures mitigating the risk of worker exposure to heat stress.

METHODS

Participants

Twenty male heat-acclimatized electric power network workers volunteered and provided written informed consent to participate in the study. Thirteen workers from the Northern region (NR), and seven workers from the Southern region (SR) were monitored on one of the five assessment days as they undertook scheduled maintenance of electrical infrastructure that included replacement of power pole components, electrical substation repairs, and transformer replacement Table I shows the personal characteristics of the participants. Heat sources were predominantly high ambient temperatures, direct sunlight, metal, gravel and concrete surfaces, and cable joining equipment. Planning, preparation of vehicles and equipment, and obtaining permits were undertaken upon commencement of the work shift. Travel to and from each work site took between 5 and 40 minutes. Workers wore hard hats, heavy-duty work boots, and 100% cotton drill long-sleeve shirt and trousers with minimum weight of $185g.m^{-2}$ according to the organizations' personal protective equipment (PPE) procedure for working near live electrical apparatus. Shift duration was approximately 8 to 12 hr, commencing at 0500 for 12 hr shifts and 0730 for 8 hr shifts.

Physiological Measures

NR participants ingested a telemetric temperature sensor (CorTemp 100, HTI Technologies, Florida, MI) with breakfast 3–4 hr prior to monitoring. Gastrointestinal temperature (T_{gi}) was determined via a handheld receiver (BCTM3, Fitsense Technologies, Southborough, MA) as often as possible without interrupting worker's activity. Heart rate was measured by a band fitted across the participant's chest (Polar, Kempele, Finland) and recorded throughout the shift. SR participants had T_{gi} measured by an ingestible temperature sensor (Jonah, VitalSense, Respronics, Pittsburgh, PA) consumed with breakfast, 3–4 hr prior to data collection. The factory-calibrated ingestible sensor transmitted T_{gi} to a wearable receiver that also recorded the heart rate (SEM, Equivital, Hidalgo Ltd., Cambridge, UK) for storage. Heart rate and T_{gi} were input into the physiological strain index [(4)] (PSI):

$$\text{Physiological Strain Index} = \left(5\frac{(T_{git} - T_{gi0})}{(39.5 - T_{gi0})} + 5\frac{(HR_t - HR_0)}{(180 - HR_0)}\right)$$

where T_{git} and HR_t are simultaneous measurements taken at any time during the exposure and T_{gi0} and HR_0 are the initial measurements.

Fluid Balance

Urine specific gravity (USG) was assessed with a calibrated refractometer (Atago UG-α, Tokyo, Japan) as an indice of hydration status pre- and post-shift, and compared to the hydration classifications of Table II.[(5)] Body mass was measured to the nearest 0.05kg in a semi-nude state on a calibrated scale (UC321, A&D Mercury, Adelaide, SA, Australia) prior to and following the work shift to determine dehydration according to the following equation:

$$\text{Dehydration}(\%) = \left(\frac{Pre - work\ shift\ body\ mass\,(kg)}{Post - work\ shift\ body\ mass\,(kg)}\right) \times 100$$

Workers had ad libitum access to their drink flask and/or fluid reservoir during the work shift. Fluid consumption was monitored by determining the mass of individual hydration reservoir and/or flask(s) pre- and post-consumption; the difference in mass was the volume of fluid consumed. Fully clothed body mass was determined immediately prior to and following toilet breaks, with the body mass difference equaling urine volume.

TABLE II. Urine Specific Gravity and Equivalent Level of Hydration

Condition	Urine Specific Gravity Value
Well Hydrated	<1.010
Minimal Dehydration	1.010 – 1.020
Significant Dehydration	1.021 – 1.030
Serious Dehydration	>1.030

Note: Data from Casa et al.[(5)]

Sweat rate was calculated by the following equation:

$$\text{Sweat rate}\,(\text{L.hr}^{-1}) = \frac{Body\ mass\ difference\,(kg) + Fluid\ consumption\,(kg) - Urine\ Volume\,(kg)}{Time\,(hours)}$$

It was assumed that 1 kg was equal to 1 L of fluid.

Environmental Thermal Measures

On each day of monitoring, dry bulb, natural wet bulb, and globe temperatures were measured at 30-minute intervals by a portable weather station (QT34, QuesTemp, Onoconomac, WI) and the outdoors wet bulb globe temperature (WBGT) index was calculated according to the following equation$^{(6)}$:

$$\text{WBGT}(^\circ\text{C}) = (0.7 \times T_{nwb}) + (0.2 \times T_g) + (0.1 \times T_a)$$

T_{nwb} = natural wet bulb temperature (represents integrated effects of humidity, radiation + wind)

T_g = globe temperature (represents integrated effects of radiation + wind)

T_a = ambient temperature

Data Treatment and Statistics

Based upon body mass and BMI differences between the cohorts, the NR and SR data were pooled to report descriptive statistics for the physiological measures, while fluid balance variables were analyzed relative to body mass.

An independent t-test was utilized to compare NR and SR cohorts for pre- and post-shift hydration differences. Sweat rate, fluid consumption, and urine volume were expressed relative to body mass prior to independent t-test analysis. A paired t-test examined differences between pooled pre- and post-fluid balance data. Statistical analysis was performed using Prism 5 software (GraphPad, La Jolla, CA) with significance set at $p < 0.05$. A statistical trend was identified by $p < 0.10$.

RESULTS

Environmental Thermal Conditions

During the monitoring, the mean ambient temperature, relative humidity, and outdoors WBGT for the NR were 33.7°C, 54%, and 32.0°C, respectively, across the 3-day period. Ambient temperature for the SR averaged 39.3°C with 9% relative humidity, resulting in mean outdoors WBGT of 28.7°C. The combined time-weighted mean outdoors WBGT was 30.8°C.

TABLE III. Combined Physiological Responses

Variable	Descriptor	Value
Core Body Temperature (°C)	Pre	37.1 (0.1)
	Mean	37.5 (0.3)
	Peak	37.9 (0.3)
Heart Rate (beats.min^{-1})	Pre	68.8 (9.8)
	Mean	103.6 (13.6)
	Peak	149.6 (9.3)
Physiological Strain Index	Mean	2.6 (0.8)
	Peak	4.6 (1.4)

Note: Data are mean (SD).

Core Body Temperature, Heart Rate, and Physiological Strain Index (PSI)

Table III summarizes the mean and peak physiological responses. Individual peak T_{gi} was 38.4°C, with four NR participants exceeding a T_{gi} of 38.0°C. The mean PSI of 2.6 equates to a descriptor of low strain, while the mean of individual peak PSI scores of 4.6 represents moderate strain. No workplace accidents were reported during the study.

Fluid Balance

There was no statistically significant change in the combined USG data from pre- to post-shift ($p = 0.372$), as presented in Figure 1. There was a trend for the SR cohort to be more dehydrated than NR counterparts prior to ($p = 0.059$), but not at the end of the work shift ($p = 0.591$). Mean sweat rate was 0.44 L.h^{-1} for the combined cohorts, with the SR cohort demonstrating a trend towards higher relative sweat rate ($p = 0.094$) and fluid consumption ($p = 0.061$), resulting in mean body mass gain of 0.5 kg compared to a mean loss of 0.4 kg for the NR participants ($p = 0.039$). The maximal body mass loss was 1.5 kg or 2.2%. Urine volume was highly variable (Table IV) with eight participants (40%) not urinating during the work shift.

DISCUSSION

Physiological Measures

Core body temperature is the key physiological variable to assess the interaction between metabolic heat production and heat dissipation to the environment, with multiple body sites used as an index of core body temperature.$^{(7)}$ The

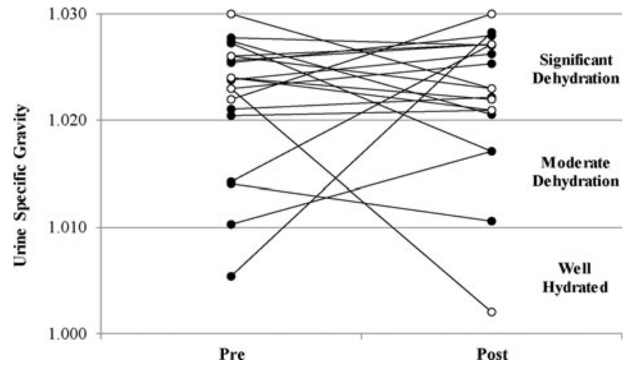

FIGURE 1. Participants' pre- and post-shift urine specific gravity results

TABLE IV. Fluid Balance Variables for the Northern and Southern region Cohorts

Variable	Combined	NR	SR	p value
Pre-Shift Urine Specific Gravity	1.022(0.006)	1.020(0.007)	1.025(0.003)	0.059•
Post-Shift Urine Specific Gravity	1.022(0.007)	1.023(0.005)	1.021(0.009)	0.591
Sweat Rate ($mL.h^{-1}.kg^{-1}$)	5.2(1.3)	4.9(1.3)	5.6(1.1)	0.104
Fluid Consumption ($mL.h^{-1}.kg^{-1}$)	5.1(2.5)	4.2(1.9)	6.8(2.8)	0.061•
Urine Volume ($mL.kg^{-1}$)	4.9(8.4)	2.9(3.2)	8.8(13.4)	0.138
Body Mass Change (kg)	−0.1(0.9)	−0.4(0.9)	0.5(0.7)	0.039*

Note: Data are mean (SD).
*denotes $p < 0.05$, • denotes $p < 0.10$.

commercialization of ingestible temperature sensors provides a relatively accurate, reliable, and acceptable index of core body temperature in the field,(8) in scenarios previously reliant on prediction of physiological responses and/or monitoring of environmental conditions. To the authors' knowledge, this study is the first to describe the physiological responses of electrical power utility crews to working in hot climates. Despite exposure to harsh environmental conditions, the T_{gi} data of the utility workers did not breach the threshold limit of 38.5°C recommended by ISO9886(9) for healthy, monitored heat-acclimatized workers, with mean T_{gi} of 37.5°C during the work shift, a mere 0.4°C above pre-shift values.

Similar findings (mean T_{gi} 37.6°C) were reported for medical responders during a simulated disaster in the NR.(10) In that study, the low PPE requirements, relatively mild environmental conditions, and low work load limited overall body heat storage. Conversely, the PPE standards of mining are similar to that of the utility workers, with miners operating in hot conditions having demonstrated comparable mean T_{gi} of 37.6°C.(11,12) The hazardous nature of firefighting requires a greater level of PPE than that worn by the utility workers with two studies reporting substantially higher T_{gi} values. In warm conditions, wildland firefighters exhibited higher mean heart rates than the participants of the current study (excess of 8 – 24 bpm), indicative of greater physical work load and therefore endogenous heat production.(13) Mean T_{gi} was 37.9 or 38.3°C dependent upon the intensity of fire suppression. In NR wet season conditions, firefighters increased their T_{gi} by 1.1°C during 30 minutes of simulated tasks in full PPE, inclusive of breathing apparatus, to attain mean T_{gi} of 38.5°C.(14) It appears that a high work load and thorough insulation of body surface area contributed to the greater body heat storage of the firefighters, two factors not as relevant to the current study.

When exposed to harsh environmental conditions, the combination of relatively low physical exertion required to complete the maintenance tasks, moderate PPE, and ability to self-pace limited utility worker body heat storage to meet the standards of ISO9886. In the absence of thorough physiological monitoring of the utility workers, as would generally be the case, the ISO9886 threshold limit is reduced to 38.0°C. Application of the lower T_{gi} limit identified four participants (20%), to have a maximal observation of 38.1 – 38.4°C. The applicability of ISO9886 and alternative standards have not been rigorously tested for staff that reside and work in warm to hot conditions year round (NR cohort), otherwise known as chronically heat-acclimatized. While the thermal work limit(15) provides allowances for heat-acclimatized staff, its restriction of work activities is based upon environmental monitoring to limit core body temperature to a conservative 38.2°C. Evidence-based core body temperature limits for resident outdoor workers of the NT are warranted, and should be expedited by the accessibility of the monitoring technology utilized in this study.

The combination of T_{gi} and heart rate data revealed low overall physiological strain interspersed with periods of moderate strain during the work shift. This outcome may be considered counter-intuitive when reviewing the environmental conditions endured by the workers, as some standards recommend severe restrictions on work time and incorporate rest periods in such climates to limit body heat storage.(16) Self-pacing by workers is a key consideration in the analysis of physiological data. By understanding the tasks required, number of staff available, time frame for completion, anticipated climatic conditions and factoring in their personal experience, physical fitness, and acute physiological status,(17,18) workers can initiate behavioral and work load adjustments, thereby selecting an appropriate pace to complete the task and prevent excessive body heat storage.(19) It is reasonable to expect that regular exposure of the utility workers to hot conditions has enabled pacing strategies to be routinely applied and modified.

In comparable environmental conditions to those of the current study, self-paced Northern Australia miners exhibited mean T_{gi} data of 37.6°C(11,12) in the absence of clinical heat stress symptoms, supporting the ability of workers to self-regulate in thermally stressful environments. These data highlight the importance of communication to provide sufficient detail facilitating informed pacing of effort, a strategy not generally associated with heat stress mitigation. Identifying circumstances that inhibit self-pacing may reveal activities likely to induce heat stress when undertaken in the hot conditions. Emergency scenarios such as power service interruptions are such an example, as workers rapidly seek to minimize the power outage and potentially priorities the restoration of power services at the expense of their acute health.

Unfortunately, there are limited data in this regard. An examination of urban search and rescue personnel (USAR) during a realistic 24-hour simulation in harsh NR conditions, resulted in 15 of 16 personnel having T_{gi} exceeding the limit of 38.5°C and six personnel exceeding 39.0°C(20) These findings confirm that emergency situations can induce high physical work loads in hot conditions, which result in physiological perturbation beyond occupational standards. Therefore, additional data are required to determine the physiological outcomes of time-sensitive electrical utility operations. In the absence of such analysis, prolonged electrical emergencies require consideration of active cooling strategies(7) to curb body heat storage. The applicability of such strategies will be site-dependent, yet with ice available at all electrical utility depots within the NT, ingestion of crushed ice is considered a potential strategy to prevent excess body heat storage of utility workers.(21)

Fluid Balance

The majority of utility workers were significantly dehydrated at the commencement and cessation of a shift, a common observation for emergency responders(22,23) and miners(11,24,25) working in similar environmental conditions. Pre-shift dehydration combined with high sweat rates can result in deteriorating hydration status. However, the mean sweat rate of 0.44L.h^{-1} was substantially lower than reported for construction activities (1.03L.h^{-1}), firefighters (0.99L.h^{-1}), and USAR operations (0.92L.h^{-1})(14,20,25) and comparable to machinery operators (0.38L.h^{-1}) and medical responders (0.54L.h^{-1}) working in Northern Australia.(10,25) Sweat rates are indicative of the maximal evaporative cooling possible, but do not account for actual heat loss by evaporation. The tropical conditions of the NR resulted in higher environmental water vapor pressure, limiting the potential for sweat evaporation. The lack of difference between regions for sweat rate expressed relative to body mass may be explained by the limited drive to dissipate body heat, as indicated by the relatively low mean T_{gi}. Under higher physical work loads, the NR workers may exhibit higher relative sweat rates than their SR counterparts due to the limited body heat dissipation via sweat evaporation in tropical settings.

Fluid consumption as a proportion of sweat rate was higher than generally reported,(26,27) indicative of adequate access to fluids on site. The trend for higher fluid consumption and body mass gain by SR workers during a shift, is likely due to their inferior hydration status before work, the reason for which is not clear. The effects of dehydration on physiological, physical, and cognitive performance are well reported in the literature.(28,29) Of the strategies that contribute to the management of heat stress, fluid consumption is widely promoted in the public domain,(30) with a concomitant focus on hydration to mitigate occupational exposure to heat stress.

Yet despite the focus on hydration management, copious fluid consumption does not confer immunity against the development of exertional heat illness in the field.(31) Rather, prevention of severe dehydration in combination with strategies that limit body heat production and/or augment body heat loss are required to limit the short-term health impacts of physical activity in hot conditions. Overall, while dehydration was evident pre- and post-shift, fluid consumption approximated sweat losses to limit mean body mass loss to just 0.1%, with only one employee exceeding the recommended 2% body mass loss limit.(32) Maintenance of this trend through daily measurement of pre- and post-shift body mass combined with improvements in pre-shift hydration on days when duties may limit access to fluids would limit the detrimental effects of dehydration. The low urine output reported by this study reflects the pre- and post-shift dehydration and could contribute to the development of nephrolithiasis(33). Workplace education packages therefore should address not only the short-term but also the long-term health implications of inadequate fluid consumption.

Workplace Accidents

The relatively brief period of physiological monitoring (five days), prevented the combined longitudinal analysis of workplace incidents, accidents, and employee physiological status. Workplace accidents are most prevalent in the hottest months of the year,(34,35) and the greatest frequency of occupational electrocutions occur during summer months,(36–38) supporting the need to quantify the relationship between environmental thermal conditions and health status for electrical utility workers. Such analysis should be prioritized throughout the NR wet season and SR summer to facilitate identification of hazardous periods to target additional monitoring and provision of cooling. In addition to the prevention of the short-term health impacts, managing heat stress is likely to have multiple positive outcomes with reference to lower individual and organizational rates of morbidity, fewer accidents, greater sense of comfort, improved renal health, increased productivity, and social well-being.(39)

Limitations

Quantification of utility worker physical activity would provide some insight into metabolic heat production; the absence of such data is a limitation of this study. The relatively small cohort and lack of participant physical fitness and anthropometric profiles limits the applicability of this research. Field-based physiological studies that address these challenges will maximize the application of study outcomes to broader occupational settings.

CONCLUSION

This investigation demonstrates that electrical utility workers undertaking self-paced work in hot conditions maintain core body temperature within the limits of ISO9886 for monitored, heat-acclimatized workers, with overall low to moderate physiological strain. While pre-shift dehydration was evident, relatively low sweat rates were matched by fluid consumption to limit body mass loss during shift. Further examination of physiological and fluid balance responses in scenarios that prevent pacing of effort are warranted.

RECOMMENDATIONS

Longitudinal examination of exposure to environmental heat, physiological responses, and workplace accidents are recommended to develop risk profiles for specific tasks in hot weather. Heat stress education sessions incorporating preventive cooling strategies and first aid procedures for heat stress in the field, are also recommended for outdoor staff prior to the NR wet season and SR summer.

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REFERENCES

1. **Coroners Court of the Northern Territory:** "*Inquest into the Death of Angus Lawrence*," by G. Cavanagh, 2005, Coroners Court of the Northern Territory, Darwin, NT 0800.
2. **Climate Commission Secretariat:** "*The Critical Decade: Climate Change and Health*," by L. Hughes and T. McMichael, 2011, Climate Commission Secretariat, Canberra, ACT 2600.
3. **Dunne, J.P., R.J. Stouffer and J.G. John:** Reductions in labour capacity from heat stress under climate warming. *Nature Clim. Change 3*(*6*):563–566 (2013).
4. **Moran, D.S., A. Shitzer, and K.B. Pandolf:** A physiological strain index to evaluate heat stress. *Am. J. Physiol. 275*(*1 Pt 2*):R129–R134 (1998).
5. **Casa, D.J., L.E. Armstrong, S.K. Hillman, et al.:** National Athletic Trainers' Association Position Statement: Fluid Replacement for Athletes. *J. Athl. Train. 35*(*2*):212–224 (2000).
6. **Yaglou, C.P.**, and **D. Minard:** Control of heat casualties at military training centers. *Arch. Indust. Health 16*:302–305 (1957).
7. **Brearley, M.**, and **P. Saunders:** Heat. In *Physiological Tests for Elite Athletes*, 2nd ed., R.K. Tanner and C.J. Gore (eds.). Champaign, IL: Human Kinetics, 2013. pp. 131–147.
8. **Casa, D.J., S.M. Becker, M.S. Ganio, et al.:** Validity of devices that assess body temperature during outdoor exercise in the heat. *J. Athl. Train. 42*(*3*):333–342 (2007).
9. **International Standards Organisation (ISO):** *Evaluation of Thermal Strain by Physiological Measurements (ISO 9886)*. [Standard] Geneva: ISO, 2008.
10. **Brearley, M.B., M.F. Heaney, and I.N. Norton:** Physiological responses of medical team members to a simulated emergency in tropical field conditions. *Prehosp. Disaster Med. 28*:139–144 (2013).
11. **Peiffer, J.J.**, and **C.R. Abbiss:** Thermal stress in North Western Australian iron ore mining staff. *Ann. Occup. Hyg. 57*(*4*):519–527 (2013).
12. **Brake, D.**, and **G. Bates:** Deep body core temperatures in industrial workers under thermal stress. *J. Occup. Environ. Med. 44*:125–135 (2002).
13. **Rodríguez-Marroyo, J.A., J.G. Villa, J. López-Satue, et al.:** Physical and thermal strain of firefighters according to the firefighting tactics used to suppress wildfires. *Ergonomics*. *54*(*11*):1101–1108 (2011).
14. **National Critical Care and Trauma Response Centre:** "*Fire Fighter Cooling in Tropical Field Conditions, 2011*," by M. Brearley, I. Norton, T. Trewin, and C. Mitchell, National Critical Care and Trauma Response Centre, Rocklands Drive, Tiwi NT 0810.
15. **Brake, D.J.**, and **G.P. Bates:** Limiting metabolic rate (thermal work limit) as an index of thermal stress. *Appl. Occup. Environ. Hyg. 17*(*3*):176–186 (2002).
16. **Parsons, K.:** Heat Stress Standard ISO 7243 and its global application. *Ind. Health 44*(*3*):368–379 (2006).
17. **Edwards, A.M., M.B. Bentley, M.E. Mann, and T.S. Seaholme:** Self-pacing in interval training: A teleoanticipatory approach. *Psychophysiology 48*(*1*):136–141 (2011).
18. **Faulkner, J., G., Parfitt, and R., Eston:** The rating of perceived exertion during competitive running scales with time. *Psychophysiology 45*(*6*):977–985 (2008).
19. **Tucker, R., T. Marle, E. Lambert, and T. Noakes:** The rate of heat storage mediates an anticipatory reduction in exercise intensity during cycling at a fixed rating of perceived exertion. *J. Physiol. 574*(*Pt 3*):905–915 (2006).
20. **Brearley, M., I. Norton, M. Hutton, et al.:** "Urban Search and Rescue Operations in Tropical Environments." Paper presented at the Science of Sport, Exercise and Physical Activity in the Tropics, Cairns, Australia, November 28–30, 2013.
21. **Brearley, M.:** Crushed ice ingestion—A practical strategy for lowering core body temperature. *J. Mil. Vet. Health 20*:25–30 (2012).
22. **Cuddy, J.S., J.A. Ham, S.G. Harger, et al.:** Effects of an electrolyte additive on hydration and drinking behavior during wildfire suppression. *Wilderness Environ. Med. 19*(*3*):172–180 (2008).
23. **Ruby, B.C., D.A. Schoeller, B.J. Sharkey, et al.:** Water turnover and changes in body composition during arduous wildfire suppression. *Med. Sci. Sports Exerc. 35*(*10*):1760–1765 (2003).
24. **Brake, D.J.**, and **G.P. Bates:** Fluid losses and hydration status of industrial workers under thermal stress working extended shifts. *Br. J. Occ. Env. Med. 60*(*2*):90–96 (2003).
25. **Miller, V.S.**, and **G.P. Bates:** Hydration of outdoor workers in north-west Australia. *J. Occup. Health Saf. Aust. N.Z. 23*:79–87 (2007).
26. **Hendrie, A.L., J.R. Brotherhood, G.M. Budd, et al.:** Project Aquarius 8. Sweating, drinking, and dehydration in men suppressing wildland fires. *Int. J. Wildland Fire 7*(*2*):145–158 (1997).
27. **Nolte, H., T.D. Noakes, and B. Van** Vuuren: Ad libitum fluid replacement in military personnel during a 4-h route march. *Med. Sci. Sports Exerc. 42*(*9*):1675–1680 (2010).
28. **Adan, A.:** Cognitive performance and dehydration. *J. Am. Coll. Nutr. 31*(*2*):71–78 (2012).
29. **Cheuvront, S.N., R. Carter, 3rd, and M.N. Sawka:** Fluid balance and endurance exercise performance. *Curr. Sports Med. Rep. 2*(*4*): 202–208 (2003).
30. **Noakes, T.D., and D.B. Speedy:** Case proven: Exercise associated hyponatraemia is due to overdrinking. So why did it take 20 years before the original evidence was accepted? *Br. J. Sports Med. 40*(*7*):567–572 (2006).
31. **Cuddy, J.S., and B.C. Ruby:** High work output combined with high ambient temperatures caused heat exhaustion in a wildland firefighter despite high fluid intake. *Wilderness Environ. Med. 22*(*2*):122–125 (2011).
32. **Sawka, M.N., L.M. Burke, E.R. Eichner, et al.:** American College of Sports Medicine position stand. Exercise and fluid replacement. *Med. Sci. Sports Exerc. 39*(*2*):377–390 (2007).
33. **Curhan, G.C., W.C. Willett, E.B. Rimm, et al.:** Prospective study of beverage use and the risk of kidney stones. *Am. J. Epidemiol. 143*(*3*):240–247 (1996).
34. **Nag, P.K., and A. Nag:** Shiftwork in the hot environment. *J. Hum. Ergol. 30*(*1–2*):161–166 (2001).

35. **Saha, A.**, **S. Kumar**, **and D.M. Vasudevan:** Occupational injury surveillance: A study in a metal smelting industry. *Indian J. Occup. Environ. Med. 11*(*3*):103–107 (2007).
36. **Lucas, J:** Electrical fatalities in Northern Ireland. *Ulster Med. J. 78*(*1*):37–42 (2009).
37. **Ore, T., and V. Casini:** Electrical fatalities among U.S. construction workers. *J. Occup. Environ. Med. 38*(*6*):587–592 (1996).
38. **Taylor, A.J.**, **G. McGwin Jr.**, **F. Valent**, **and L.W. Rue**. **3rd:** Fatal occupational electrocutions in the United States. *Inj. Prev. 8*(*4*):306–312 (2002).
39. **Ayyappan, R.**, **S. Sankar**, **P. Rajkumar**, **and K. Balakrishnan:** Work-related heat stress concerns in automotive industries: A case study from Chennai, India. *Glob. Health Action 11*:2 (2009).