Pre-deployment Heat Acclimatization Guidelines for Disaster Responders

Matt B. Brearley, PhD, BHMS(Hons), BBus

Disaster Medicine Research, National Critical Care and Trauma Response Centre, Darwin, Northern Territory, Australia

Correspondence:
Matt Brearley, PhD, BHMS(Hons), BBus
National Critical Care and Trauma Response Centre
Royal Darwin Hospital
Rocklands Drive, Tiwi
Northern Territory, Australia 0810
E-mail: matt.brearley@nt.gov.au

Conflicts of interest: none

Keywords: deployment; disaster; guidelines; heat acclimatization; thermal

Abbreviations:
AusMAT: Australian Medical Assistance Team
RPE: rate of perceived exertion
T_c: core body temperature

Received: May 25, 2015
Revised: August 4, 2015
Accepted: August 16, 2015

doi:10.1017/S1049023X15005476

Abstract

Introduction: Minimal preparation time is a feature of responding to sudden onset disasters. While equipment and supplies are prepared for deployment at short notice, less is known of the physical preparation of medical responders. With many disaster-prone areas classified as tropical regions, there is potential for responders to endure a combination of high ambient temperatures and relative humidity during deployment. Heat acclimatization, defined as the physiological and perceptual adaptations to frequent elevations of core body temperature (T_c), is a key strategy to improve tolerance of hot conditions by medical responders.

Methods: Pre-deployment heat acclimatization guidelines were developed based upon the duration of physical training and the subjective rate of perceived exertion (session RPE). An objective of individual training sessions was the perception of body temperature as warm to hot. The guidelines were implemented for Team Bravo (2nd rotation) of the Australian Medical Assistance Team (AusMAT) deployed to Tacloban, Philippines following Typhoon Haiyan in November 2013. The guidelines were distributed electronically five to seven days prior to deployment and were followed by a consultation. A group training session in hot conditions was undertaken prior to departure.

Results: The AusMAT responders to utilize the guidelines were based in cool or temperate climates that required extra layers of clothing, training during warmer parts of the days, or warm indoor conditions to achieve session objectives. Responders reported the guidelines were simple to use, applicable to their varied training regimens, and had improved their confidence to work in the heat despite not completing the entire 14 day period.

Conclusion: The pre-deployment heat acclimatization guidelines provided AusMAT responders the ability to quantify their physical training and promoted physiological adaptations to maximize health, safety, and performance during deployment. While maintaining year-round heat acclimatization is considered essential for medical responders, these guidelines may facilitate beneficial adaptations once notified of deployment.

Brearley MB. Pre-deployment heat acclimatization guidelines for disaster responders. *Prehosp Disaster Med*. 2016;31(1):1-5.

Introduction

Responding to sudden onset disasters is unpredictable with the likelihood for short lead-in times. While equipment and supplies are prepared for deployment with minimal notice, less is known of the physiological readiness of medical teams to respond. Australia's proximity to the Asia-Pacific region, the world's most disaster-prone and vulnerable locality,[1] increases the probability of an Australian Medical Assistance Team (AusMAT; Northern Territory, Australia) deployment to a tropical climate. Given that AusMATs typically are comprised of members residing in diverse locations and prevailing climates, mitigating the impact of heat stress during deployment is a key health and safety consideration. Heat stress has been documented for disaster responders,[2–4] and brief, generalized recommendations exist for the prevention of heat-related illnesses in disaster response teams working in tropical regions.[5] Specifically, heat stress education, work scheduling, sleep, provision of hydration and nutrition, monitoring of the team, and cooling are proposed to limit the impact of the environment on the disaster response.

In recent years, AusMATs have been deployed to a variety of hot, and in some cases humid, environments (eg, Northern Australia, Pakistan, Philippines, Timor Leste,

Week 1	Week 2
Expansion of Plasma Volume	Decreased Resting Core Body Temperature
Increased Cutaneous Blood Flow	Decreased Exercise Core Body Temperature
Deceased Heart Rate	Increased Sweat Secretion
Decreased Perception of Effort	

Table 1. Adaptations Typically Observed during Heat Acclimatization

and Vanuatu). To mitigate heat stress, team members have been exposed to practical heat stress education during mandatory training and are briefed on the specific measures to combat heat stress prior to each deployment. During deployment, AusMAT members can expect to work 12-hour shifts for approximately 14 days.[6,7] While pacing of effort to limit body heat production can be an effective heat stress mitigation strategy,[8] this approach may be compromised within the work schedule as responders prioritize the health of patients ahead of their personal well-being. The provision of cool sleeping conditions is an objective; however, AusMAT members typically sleep in non-climate-controlled settings, experiencing camp conditions with the possibility of warm to hot nights. Each responder is issued with a hydration bladder/backpack and has access to bottled water, carbohydrate/electrolyte solutions, and quality rations they are familiar with to limit dehydration and malnutrition. Cooling strategies have proven effective for reducing emergency responder thermal burden during simulations[9,10] and are utilized during deployment, where appropriate. Austere, resource-limited settings, however, are likely to hinder implementation of such measures. Lastly, well-being monitoring of AusMAT members is achieved by a daily electronic questionnaire assessing perceived workload, access to food and fluids, sleep factors, and heat stress.[11]

Despite the aforementioned suite of strategies, the thermal burden of a hot environment remains amplified for individuals unaccustomed to working in the heat. Therefore, heat acclimatization, defined as the physiological and perceptual adaptations to frequent elevations of core body temperature (T_c) in the natural environment, is an approach worthy of consideration to complement the aforementioned recommendations and to improve tolerance of disaster responders to hot working conditions. Heat acclimation refers to the same process as heat acclimatization, although it is achieved via simulated conditions. Given the similar benefits, no distinction between acclimatization and acclimation are made within this report.

Report

Technical Background

The adaptations conferred by heat acclimatization in controlled settings include lower resting T_c,[12] lower T_c and heart rate for a given exercise intensity,[13] an earlier onset of sweating,[14] and an increased capacity to sweat.[15] Beneficial adaptations generally manifest during repeated exercise sessions over approximately two weeks, as summarized by Table 1; however, the precise time course of adaptations is influenced by individual factors, including physical fitness and training history.[16]

Based upon the laboratory findings, heat-acclimatized disaster responders deployed to the tropics are expected to experience lower T_c and less physiological strain than their non-heat-acclimatized counterparts. However, in practice, where pacing of effort is not fixed, the opposite effect has been reported.[17] Urban search and rescue personnel from tropical (n = 8) and temperate/subtropical regions (n = 8) were monitored during the initial shift of a 24-hour exercise in hot and humid conditions (34.0°C; 48% relative humidity). While similar mean T_c between groups was noted during the early stages of shift, thereafter, mean T_c for the heat-acclimatized responders was significantly higher than that of the non-heat-acclimatized cohort. This counter intuitive finding appears due to the responders pacing their effort according to how they felt, as both heat-acclimatized and non-heat-acclimatized groups reported a comparable thermal sensation during the shift, despite the T_c discrepancy. It's probable that regular exposure of the heat-acclimatized cohort to working in warmer conditions, compared to their non-heat-acclimatized counterparts, promoted adaptations to elevated T_c in their daily work environment that permitted tolerance of higher T_c. To achieve the higher T_c, it's proposed that the heat-acclimatized cohort self-selected a higher workload (and higher metabolic heat production) and were therefore likely to be more productive during the initial shift. Furthermore, five of the non-heat-acclimatized responders, and only two of the heat-acclimatized responders, reported symptoms of nausea and headache during the 24-hour response. Collectively, the improved thermal tolerance of the heat-acclimatized group permitted higher T_c to be sustained and lower incidence of minor heat-related symptoms.

For workers not chronically exposed to hot conditions, heat acclimatization can be achieved through a graded exposure to hot working environments. The National Institute of Occupational Safety and Health (Centers for Disease Control and Prevention; Atlanta, Georgia USA) prescribe a maximum 20% exposure to hot working conditions on day one of exposure, progressively increasing to 100% exposure on day five, for those unaccustomed to working in the heat.[18] Previous experience in the heat increases the prescribed load to 50% on day one and 100% on day four. Such work restrictions appear untenable for non-heat-acclimatized disaster responders deployed to the tropics, as workload is typically highest during the initial stages of response.[19] In the AusMAT context, the high priority, physically demanding tasks of establishing medical treatment facilities and habitat precede treatment of patients. Restrictive work scheduling during this period would require excessively large teams and additional resources that are likely not only to delay deployment, but also curb productivity once on the ground. A greater emphasis is therefore placed upon responder heat acclimatization in the home environment. The challenge faced by emergency response organizations/agencies in this respect is the development and maintenance of a heat-acclimatized pool of responders year round, irrespective of locality and prevailing climate. The task is further complicated by individual factors such as physical fitness and training history influencing the time course and maintenance of heat acclimatization. This report addresses such issues by providing guidelines for disaster responders to achieve heat acclimatization prior to deployment through physical training irrespective of fitness status.

Applied Cases

The aforementioned pre-deployment heat acclimatization guidelines were utilized during the November 2013 AusMAT response to Typhoon Haiyan in Tacloban, Philippines. For an overview of the AusMAT response, see Coatsworth.[7] The initial AusMAT (team Alpha) was comprised of 37 members deployed with approximately 24 hours notice, an inadequate time frame to develop heat acclimatization. The majority of team Alpha (27 of 37) was drawn from the tropics of Northern Australia, with the remaining 10 members residing in cooler regions. Team Alpha experienced a large clinical workload and were relieved after 14 days by a second AusMAT (team Bravo), who officially were notified of their selection five to seven days prior to deployment. In contrast to team Alpha, only 12 of the 37 responders resided in tropical regions, resulting in deployment of 25 responders from cool, temperate, or subtropical climates. All team Bravo responders were provided with the heat acclimatization guidelines contained within this report; however, most attention was focused on the 25 responders who were broadly classified as non-heat-acclimatized responders. Following electronic communication of the guidelines and basic instructions, individual phone calls provided the opportunity to discuss the recommendations and how they may be achieved. Use of the guidelines was optional, with seven members utilizing the guidelines throughout the five to seven day pre-deployment period.

The prevailing cool/temperate climates of the seven responders precipitated the use of additional layers of clothing to restrict body heat loss during training, conducting sessions during the warmest part of the day, or utilizing warm indoor conditions. A group training session in warm conditions with the seven responders and author was undertaken in Darwin, Northern Territory, Australia on the afternoon prior to departing for the Philippines. Anecdotal feedback from the seven responders described the guidelines as simple to use, applicable to their varied training regimens, and having improved their confidence to work in the heat despite not completing the entire 14 day period.

Detailed Protocol

The primary impetus for heat acclimatization is an elevated T_c.[20] Given that the recommended upper T_c limit of 38.0°C and 38.5°C for non-heat-acclimatized and heat-acclimatized workers, respectively,[21] the purpose of initial training sessions is to elevate and maintain T_c at approximately 38.0°C, with a T_c target of 38.5°C upon achieving partial heat acclimatization. The lack of valid T_c data feedback during training compels reliance on thermal sensation to determine pacing. An overall body temperature perception of warm to hot is considered appropriate during heat-acclimatization sessions (Table 2,[22]). While partial heat acclimatization can result from sustained passive heat exposure,[23] this approach is not advocated due to limited advantages observed during physical activity in the heat, poor time efficiency, and the high levels of perceptual strain experienced. The preferred approach couples physical activity as an endogenous heat source with restricted heat dissipation to promote elevated T_c.

Rating	Descriptor
1	Unbearably Cold
2	Extremely Cold
3	Very Cold
4	Cold
5	Cool
6	Slightly Cool
7	Neutral
8	Slightly Warm
9	Warm
10	Hot
11	Very Hot
12	Extremely Hot
13	Unbearably Hot

Table 2. Thermal Sensation Scale (modified from Gagge et al[22]). Responders use this scale to rate their perceived thermal sensation during exercise sessions with a goal of Warm (9) to Hot (10).

Physical training programs generally use the parameters of training type, duration, and/or distance to elicit the desired training load. When applied to groups, this approach can produce varied responses to a given session due to contrasting training experience. Hence, the generic prescription of physical training to promote heat acclimatization is not likely to succeed when applied to a heterogeneous range of individuals. A more subjective approach appears warranted for disaster responders. Initially proposed by Foster et al.[24] to quantify training loads, the session rate of perceived exertion (RPE) method has been implemented broadly in athletic settings. Training load is calculated by multiplying the duration of the session (in minutes) by the intensity or RPE of the session (Table 3), as used by Borg et al.[25] For example, a 30-minute session that was rated as moderate (equivalent RPE rating of 3) would be calculated as follows: $30 \times 3 = 90$ units. Use of the session RPE approach overcomes the generic prescription of training, instead relying on each individual's perception of effort. Responders were instructed to utilize session RPE to quantify and compare their training workload to the suggested classifications of Table 4.

Distinct heat acclimatization guidelines are provided for two physical training groups: minimally trained (inconsistent training history in previous three months, averaging less than five hours physical training per week) and trained (greater than five hours physical training per week incorporating some moderate intensity). Minimally trained disaster responders require a 14-day program to achieve heat acclimatization (commencing day one), whereas trained individuals are considered to be partially heat acclimatized, requiring the abbreviated time frame of seven days

Rating	Descriptor
0	Nothing at All
0.5	Very, Very Light
1	Very Light
2	Fairly Light
3	Moderate
4	Somewhat Hard
5	Hard
6	
7	Very Hard
8	
9	
10	Very, Very Hard

Table 3. Rate of Perceived Exertion Scale (Borg et al[25]). Responders use this scale to rate their perceived exertion during exercise sessions. The rating is multiplied by session duration (minutes) for calculation of session score.

(commencing from day eight). Table 4 details example sessions utilizing brisk walking to demonstrate the recommended progressive training load.

Future Developments

Following the uptake of the optional heat acclimatization guidelines, the program is now considered a mandatory element for AusMAT members prior to deploying in the heat. Extension of the session RPE method to incorporate thermal sensation is a potential development, as a "session-thermal sensation" may be more appropriate to quantify pre-deployment heat exposure. Testing of responders to assess the physiological impact of the heat acclimatization guidelines is warranted, potentially leading to evidence-based training load recommendations. Lastly, monitoring the session RPE and session-thermal sensation of each shift while on deployment is also an objective to provide insight into heat acclimatization loads while responding. The AusMAT electronic questionnaire permits such monitoring in a time efficient manner.[11]

Days	Score	Example Sessions
1-2	80-120	40 minutes of brisk walking (3/moderate)
3-4	120-180	50 minutes of brisk walking (3/moderate)
5-6	180-220	70 minutes of brisk walking (3/moderate)
7	-	Recovery day to assist adaptation
8-10	220-250	80 minutes of brisk walking (3/moderate)
10-14	250 +	90 minutes of brisk walking (3/moderate)

Table 4. Pre-deployment Exercise Session Guidelines for Disaster Responders. Score is the product of exercise duration (minutes) and rating of perceived exertion from Table 3.

Conclusion

This report proposes disaster responder heat acclimatization prior to deployment through physical training and provides guidance for its achievement based upon responder subjective ratings. The guidelines accommodate responders with and without a recent history of physical training and can be implemented irrespective of local climate. It is anticipated that when used in conjunction with other heat stress mitigation strategies, pre-deployment heat acclimatization will contribute to maximizing the health, safety, and performance of disaster responders in tropical settings.

References

1. United Nations. Statistical Yearbook for Asia and the Pacific 2014, http://www.unescap.org/resources/statistical-yearbook-asia-and-pacific-2014. Published 2014. Accessed May 4, 2015.
2. Dellinger AM, Kachur SP, Sternberg E, Russell J. Risk of heat-related injury to disaster relief workers in a slow-onset flood disaster. *J Occup Environ Med*. 1996;38(7):689-692.
3. Mori K, Tateishi S, Hiraoka K, et al. How occupational health can contribute in a disaster and what we should prepare for the future-lessons learned through support activities of a medical school at the Fukushima Daiichi Nuclear Power Plant in summer 2011. *J Occup Health*. 2013;55(1):6-10.
4. Rusiecki JA, Thomas DL, Chen L, Funk R, McKibben J, Dayton MR. Disaster-related exposures and health effects among US Coast Guard responders to Hurricanes Katrina and Rita: a cross-sectional study. *J Occup Environ Med*. 2014;56(8):820-833.
5. Li X, Hou S, Zheng J, Fan H, Song J. Post-disaster medical rescue strategy in tropical regions. *World Journal Emerg Med*. 2012;3(1):23-28.
6. Aitken P, Leggat P, Robertson A, Harley H, Speare R, Leclercq M. Health and safety aspects of deployment of Australian disaster medical assistance team members: results of a national survey. *Travel Med Infect Dis*. 2009;7(5):284-290.
7. Coatsworth NR. The Australian medical response to Typhoon Haiyan. *Med J Aust*. 2014;201(11):632-634.
8. Brearley M, Harrington P, Lee D, Taylor R. Working in hot conditions-a study of electrical utility workers in the northern territory of Australia. *J Occup Environ Hyg*. 2015;12(3):156-162.
9. Walker A, Driller M, Brearley M, Argus C, Rattray B. Cold-water immersion and iced-slush ingestion are effective at cooling firefighters following a simulated search and rescue task in a hot environment. *Appl Physiol Nutr Metab*. 2014;39(10):1159-1166.
10. Brearley M, Norton I, Trewin T, Mitchell C. Fire fighter cooling in tropical field conditions. National Critical Care and Trauma Response Centre. http://www.territorystories.nt.gov.au/bitstream/10070/252355/1/Fire%20Fighters%20Report%20Final.pdf. Published 2011. Accessed May 4, 2015.
11. Brearley M, Ruskie S. Development of a disaster nurse well-being instrument. *Prehosp Disaster Med*. 2015;30(Supplement 1):s116.
12. Kampmann B, Bröde P, Schütte M, Griefahn B. Lowering of resting core temperature during acclimation is influenced by exercise stimulus. *Eur J Appl Physiol*. 2008;104(2):321-327.
13. Burk A, Timpmann S, Kreegipuu K, Tamm M, Unt E, Oöpik V. Effects of heat acclimation on endurance capacity and prolactin response to exercise in the heat. *Eur J Appl Physiol*. 2012;112(12):4091-4101.
14. Yamazaki F, Hamasaki K. Heat acclimation increases skin vasodilatation and sweating but not cardiac baroreflex responses in heat-stressed humans. *J Appl Physiol*. 2003;95(4):1567-1574.
15. Armstrong CG, Kenney WL. Effects of age and acclimation on responses to passive heat exposure. *J Appl Physiol*. 1993;75(5):2162-2167.
16. Pandolf KB, Burse RL, Goldman RF. Role of physical fitness in heat acclimatization, decay and re-induction. *Ergonomics*. 1977;20(4):399-408.
17. Brearley M, Norton I, Hutton M, Rush D, Smith S, Fuentes H. Urban search and rescue operations in tropical climates. Paper presented at: Bushfire and Natural Hazards CRC and AFAC Wellington Conference; September 2-4, 2014; Wellington, New Zealand.

18. Acclimatization. Centers for Disease Control and Prevention Web site. http://www.cdc.gov/niosh/topics/heatstress/acclima.html. Accessed May 4, 2015.
19. Read DJ, Holian A, Moller CC, Poutawera V. Surgical workload of an Australian foreign medical team after Typhoon Haiyan. *ANZ J Surg*. Epub ahead of print May 2015. doi: 10.1111/ans.13175.
20. Chueng S. *Advanced Environmental Physiology*. Champaign, Illinois USA: Human Kinetics; 2010.
21. International Organization for Standardization. *ISO 9886:2004(E)*. Geneva, Switzerland; 2004.
22. Gagge AP, Stolwijk JA, Hardy JD. Comfort and thermal sensations and associated physiological responses at various ambient temperatures. *Environ Res*. 1967;1(1):1-20.
23. Lim CL, Chung KK, Hock LL. The effects of prolonged passive heat exposure and basic military training on thermoregulatory and cardiovascular responses in recruits from a tropical country. *Mil Med*. 1997;162(9):623-627.
24. Foster C, Florhaug JA, Franklin J, et al. A new approach to monitoring exercise training. *J Strength Cond Res*. 2001;15(1):109-115.
25. Borg G. *Borg's Perceived Exertion and Pain Scales*. Champaign, Illinois USA: Human Kinetics; 1998.