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PRACTITONER'S CORNER:
Revisiting exertional heat stress: A field-worker's case study

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Abstract

Objective. The case study reports an incident of heat stress occurring during an archeological dig and discusses measures for the prevention and treatment of such incidents. **Methods**. The case is described by an exercise physiologist/nurse who attended the scene and followed the outcome. **Results**. On her third day at the site an 18-year-old Canadian university student (body mass index = 23 kg/m^2) reported tremors, dizziness, headache, chills, and nausea following vomiting and diarrhoea. The initial assessment demonstrated a fever, and treatment included oral acetaminophen, an anti-emetic, pro-biotics, and Vitamin B and C supplements. Persistent chills and tremors necessitated a second opinion, leading to a diagnosis of heat exhaustion. The emergency department administered 1 L of cold IV fluid, and recommended return to work as tolerated, with a daily fluid-intake of at least 3 L. The subsequent prognosis was good. **Conclusions**. This case is a unique recorded example of heat exhaustion in archeological excavation but emphasizes that heat stress can occur in many classes of outdoor workers, as well as in athletes and employees in hot indoor environments. Individuals who are un-acclimatized and dehydrated are particularly vulnerable. The use of tools to assess the severity of heat exposure and an awareness of risk factors and possible symptoms can help in flagging those at risk. Preventive measures (prior heat acclimation, precooling and adequate hydration and rest periods) can also help to decrease the risk and severity of heat-related incidents. **Health & Fitness Journal of Canada 2019;12(3):166-176**.

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Introduction

Global warming and related prolonged and severe heat waves are exposing many who engage in outdoor physical activity to the various types of heat illness. Participants in organized events such as marathon runs and football games and workers in deep South African gold mines have some protection from climatic limits established by years of practical experience (Hargreaves, 2008; Howe & Boden, 2007; Webber, Franz, Marx, & Schitte, 2003), but other outdoor workers in fitness and recreational classes, provincial and national parks programmes, and agriculture may have much longer exposure, with few guidelines, little supervision, and sometimes limited availability of replacement fluids (Eisenberg & Metthner, 2014; Methner & Eisenberg, 2018). The potential danger seems particularly great when students travel from temperate climates to work at archaeological excavations in much hotter climates, although there seems to have been no previous documentation of resulting problems. The present report describes an initially unrecognized case of heat stress in an Ontario student working at an archaeological site in Macedonia.

Methods

Details of the case were observed and recorded by an exercise physiologist and registered nurse with expertise in laboratory-based environmental stress research (Brenner, Shek, Zamecnik, & Shephard, 1998). The affected student was engaged in archaeological excavation for 5 hr/d at a temperature of ~ 38 ° C, ~50% relative humidity, with little protection from solar radiation. The student's required activities included moving layers of soil and transporting this soil in a heavy wheelbarrow to a truck and cleaning a small localized area of the site. The student succumbed to heat exhaustion during Day 3 of her first week at the dig site, needing urgent hospital treatment.

Results

The case that is described here occurred during a heat wave in Macedonia. The daytime temperature was 38 °C, ~50% relative humidity. On the third day of work at an archaeological site, an 18-year-old Caucasian female (body mass = 63.5 kg; height = 1.68 m) presented herself to the excavation director following a period of nausea and vomiting, with complaint of tremors, fatigue, chills, headache and dizziness. She had no previous medical conditions, was not taking any medication, and had no history of exertional heat illness, but she was not heat acclimatized. The site offered little protection from solar radiation, and there was little opportunity for rest breaks or fluid replacement.

Initial treatment consisted of 1 d of rest in an air-conditioned-room, drinking water and carbohydrate-electrolyte beverages as tolerated and the administration of pro-biotics. When symptoms did not improve, she was taken for medical assessment to a local clinic. Her resting HR was elevated (140 beats/min), her blood pressure was low (110/60 mm Hg) and her oral temperature was 38 °C. Based upon these findings, a diagnosis of "fever" was made, and the patient was treated orally with acetaminophen, an anti-emetic (metoclopramide hydrochloride), Vitamin B and C and electrolytes. With continued chills and dizziness, and still feeling unwell, she was taken to a city hospital for further assessment. At the hospital, her vital signs remained similar with an elevated resting heart rate, a low blood pressure and a slight elevation of body temperature. However, blood work (complete blood counts, hemoglobin, hematocrit, blood sugar and electrolytes) and electrocardiogram (ECG) recordings were all reported as normal. A diagnosis of heat exhaustion was made based upon the patient's symptoms and vital signs.

Chilled fluids were administered intravenously: 500 mL of normal saline with Vitamin B and C and 500 mL of a 5% dextrose solution. Following this, she was advised to drink 3 L of water a day and to return to work as tolerated. Fortunately, the heat exhaustion was caught early on and her condition did not progress to any more serious complication of heat exposure.

Discussion

This incident underlines the need for greater knowledge of the risks of heat illness in those who are physically active outdoors during the summer months, with implications for the recognition of heat stress, its risk factors, treatment and prevention.

Recognizing signs and symptoms of heat stress

Early recognition of the signs and symptoms of heat stress is important to decreasing its incidence. Heat stress can be quantified as the sum of the heat generated in the body (metabolic heat) plus the heat gained from the environment (environmental heat) minus bodily heat loss to the environment (Nerbass et al., 2017). The resulting physiological responses have been referred to as heat strain, with illnesses that can range from mild/moderate to life threatening (Casa et al., 2015).

Heat cramps

Exercise-associated muscle cramps (EAMC) are often the first manifestation, and are not always associated with heat exposure (Casa et al., 2015). They are characterized by twinges, tremors, muscle contractures and full-blown cramps which can be both observed and characterized by electromyography (EMG) recording. Causative factors include dehydration, electrolyte imbalances, fatigue and changes in neuromuscular control.

Heat syncope

Muscle cramps may be followed by heat syncope (Casa et al., 2015). Heat syncope is marked by feelings of dizziness and light-headedness with prolonged standing or postural change. Heat syncope is common in individuals who are unfit and/or are unaccustomed to high ambient temperatures, particularly during the first 5 d of heat exposure. There is extensive peripheral vasodilatation and venous pooling. Anecdotal reports have suggested that lack of calcium may contribute to this problem; previous individuals who succumbed to heat syncope in Macedonia were resuscitated and then treated with calcium supplements. Calcium has a role in regulating venoconstriction and decreasing venous pooling (Amberg & Navedo, 2013), thus conserving blood flow to the brain.

Heat exhaustion

If core body temperature continues to rise between 38 °C and 40.5 ° C, there is the possibility of progressing to heat exhaustion (Casa et al., 2015). At this stage, there is an increase in skin blood flow, profuse sweating and dehydration. Heat exhaustion is one of the most common forms of heat illness. It is rapid in onset and brief in duration. It occurs most commonly in hot, humid conditions (as in the present case study) but can also occur in more temperate environmental conditions during periods of intense physical activity and in athletes who wear heavy protective gear (for example, at football training camps in the early fall). The symptoms of heat exhaustion include muscle cramps, syncope, weakness, fatigue, headache, a dark-coloured urine, nausea, vomiting, tachycardia, hypotension, chills, "goose bumps", ataxia and an altered mental status (Coris, Ramirez, & Van Durme, 2004).

Heat stroke

If core body temperature exceeds 40.5° C (105 ° F), heat stroke may develop (Casa et al., 2015). One of the first signs of heat stroke is neurological dysfunction (as demonstrated by irritability, confusion, seizures, altered consciousness and collapse). There is a cessation of sweating, followed by a systemic inflammatory response and multi-systemic organ failure. Heat stroke is ranked as the third-highest exercise-related cause of death (Merkel & Molony, 2012).

Differential diagnosis

In the present case study, a differential diagnosis was difficult, as all of the initial signs and symptoms could have been due to influenza or some other infectious illness. Indeed, the initial diagnosis was a fever; although the student complained of tremors, there were no obvious skeletal muscle cramps. The main features were a mild fever (a body temperature of 38 °C), headaches, nausea and vomiting. Repeated symptoms of dizziness, fatigue and tachycardia, a low blood pressure, and a history of physical work in severe heat finally allowed the correct diagnosis of heat exhaustion to be reached.

Appropriate treatment

The appropriate treatment of a heat-related illness depends its type and severity (Merkel & Molony, 2012). For EAMC, active stretching and massage plus rehydration with beverages containing an appropriate sodium content is usually sufficient. For those with heat syncope, the supine position, with the legs elevated helps with venous return and decreases symptoms of dizziness. Athletes and workers who develop heat exhaustion should cease physical activity and be treated with hydration and body cooling. Elevation of the legs is again recommended. Heat stroke is a medical emergency. Rapid cooling of the body is required through submersion in ice-cold water baths, hosing down with cold water or applying ice packs to the groin and armpits.

In the case study presented here, the student was immediately removed from the field, and allowed to rest in a cool environment with oral hydration, followed (after hospital admission) by the administration of 1 litre of cold intravenous fluids.

Risk factors for developing exertional heat illness

Awareness of the risk factors that increase susceptibility to heat illness may help a physician, paramedic or work supervisor to identify vulnerable individuals, and to institute preventive measures. Among many risk factors, we may highlight hydration status, sex, sleep deprivation, ethnicity, training status, a lack of heat acclimatization, age, prior history of heat illness and immune function (presence or absence of infection) (Casadio, Kilding, Cotter, & Laursen, 2017).

Hydration status

Dehydration is the main risk factor associated with heat illnesses (Coris et al., 2004). By definition, clinical dehydration is a 6% decrease in body mass (Lapides, Bourne, & Maclean, 1965), with a serum osmolality above 295 mOsml/L (Shimizu et al., 2012).

Symptoms of dehydration include thirst, a flushed face and a decrease in physical performance, whereas the classical physical signs of dehydration include a dry mouth, dry axillae, a decreased skin turgor, a reduced tongue turgidity, the development of furrows or folds in the tongue. a delayed capillary refill time, sunken eyes and decreased level of consciousness (Lapides et al., 1965; Shimizu et al., 2012).

Not only does dehydration affect physical endurance, with a reduction in tolerance times for exhausting exercise (McLellan et al., 1999), but it also induces physiological changes that can compound heat stress. For example, for every one percent (1%) of body weight loss through dehydration, core body temperature rises 0.15 – 0.2° C (Coris et al., 2004). Moreover, the increased cardiovascular strain induced by 1% dehydration is reflected in a heart rate increase of 3 – 5 beats per min.

Heat loss through evaporation is also compromised by dehydration. All of these variables (core temperature rise, cardiovascular strain and decreased evaporative heat loss) contribute towards bodily heat strain.

Sex and ethnicity

Biological factors such as sex and ethnicity influence vulnerability to heat strain. Compared to men, women are more vulnerable to heat-related illnesses. Females have a higher threshold before they begin to sweat and sweat less than males (Casadio et al., 2017). Furthermore, sleep deprivation in women increases the severity of heat-illness symptoms without altering the physiological strain (Relf et al., 2018).

For pre-menopausal women, other factors to consider include the phase of the menstrual cycle and use of oral contraceptives. The menstrual cycle alters temperature regulation, primarily due to the presence of progesterone in the luteal phase (Carpenter & Nunneley, 1988). During the post-ovulatory period, resting body temperature can increase by as much as 0.3 – 0.4 °C and the threshold for the onset of sweating, cutaneous dilation and skin blood flow is set 0.5 °C higher (Kolka & Stephenson, 1989). Oral contraceptive use, which combines estrogen and progesterone, can attenuate the luteal-phase rise in core body temperature observed in non-contraceptive users, as it seems to dampen any cycle-related circadian variation. As a result, heat tolerance is increased in women taking oral contraceptives (Tenaglia, McLellan, & Klentrou, 1999).

In an epidemiological study examining hospitalizations and deaths due to heat illness in soldiers from 1980 – 2002, Carter et al. (2005) found that Caucasians were more likely to succumb to heat illness compared to other ethnic groups. For example, 66.7% of Caucasians succumbed to heat-illness, compared to 23.6% of Blacks, 2.4% of Asians, 4.5% of Hispanics and 2.8% of other ethnic minorities. It is possible that ethnic groups with origins from warmer climates (by simply having had the opportunity to adapt to heat) may have an increase in cellular heat shock protein content with heat exposure (Lyashko et al., 1994) or an enhanced sudomotor function (increasing the cholinergic sensitivity of sweat glands and enhancing the distribution of sweating) (Taylor, 2014). Heat shock proteins are known to protect the cell against heat stress and increased sensitivity to acetylcholine may facilitate sweating.

Cardio-respiratory training status

Physical training enhances the ability to withstand thermal stress. For example, endurance athletes have a greater ability to lose heat via sweating (i.e., evaporative cooling) as opposed to sprint athletes and it is thought that this is related to an individual's maximal aerobic power (Casadio et al., 2017).

Other risk factors

Other factors such as age, body composition, prior history of heat illness and presence of infection have been identified by Casadio et al. (2017). Children and the elderly have more difficulty with heat tolerance due to impairments in their thermoregulatory function (Drinkwater & Horvath, 1979). Moreover, individuals with greater adiposity show a faster rise in core body temperature during heat exposure. Previous heat illness also makes an individual more susceptible to a subsequent heat injury. Lastly, having an infection with an accompanying fever predisposes an individual to thermal stress.

In the case study presented here, the affected individual was a young and healthy Caucasian 18-year old female with a BMI of 23 kg/m^2. She did not use oral contraceptives and was in her luteal phase when she began excavating. Her sex and ethnicity made her more vulnerable to heat stress than some of her co-workers. Not being accustomed to fluid replacement protocols in the heat, she did not drink sufficient fluids, and became dehydrated. Moreover, she had not performed any physical training for over a year, and she was not heat acclimatized, having left Canada when the daytime ambient temperature was 15 – 18 °C. Finally, both sex-specific factors lead to an elevation in her resting core body temperature.

Methods of monitoring heat stress

Several tools are available to monitor environmental heat stress and to determine the safety of those who need to work or exercise in heat, including the wet bulb globe thermometer, the predicted heat strain and the heat illness symptom index.

Wet bulb globe thermometer

One of the first important tools, introduced in the late 1950's by the military is the wet-bulb globe temperature (WBGT) (Minard, Belding, & Kingston, 1957). Introduction of the WBGT decreased military heat casualties from 12.4/10,000 cases to 4.67/10,000 cases, despite higher environmental temperatures. The WBGT is a measure of heat stress in direct sunlight and it takes into account factors such as the ambient temperature, relative humidity, radiation (including sun angle and cloud cover) and wind speed (Arbury, Lindsley, & Hodgson, 2016). It has become an international standard for safe heat exposure (Nerbass et al., 2017). Recorded WBGTs are classified according to temperature into white (78.0 - 81.9 °C), green (82.0 – 84.9 °C), yellow (85.0 – 87.9° C), red (88.0 – 89.9 °C) and black (> 90 °C) categories (Luippold et al., 2018). Work to rest ratios as well as suggested fluid consumption have been prescribed based upon these temperature zones.

Predicted heat strain (PHS)

The PHS is based upon human body-heat equations that account for climatic (air temperature, radiant temperature, humidity and air movement) and non-climatic factors (clothing and metabolic heat) involved in heat transfer (Nerbass et al., 2017). The humidity index (HI) system (Humidex) is a dimensionless unit that combines temperature and humidity into a single value; the humidex is used by some Governmental Environmental Bureaus (for example, Environment Canada) to indicate how hot the weather may feel to an average person. Measures of thermal humidity can be taken using a thermal hygrometer (available at hardware or office supply stores). A humidex greater than 35 would indicate a hot workplace environment. The humidex reading can be adjusted for radiant heat by adding “2 – 3” to the reading, for work done in direct sunlight between 10:00 am and 5:00 pm.

Heat Illness Symptom Index

The heat illness symptom index (HISI) is a recent instrument that has been designed to assess heat illness in athletes. It consists of 11 items of possible symptoms of heat illness including: feeling tired, cramps, nausea, dizziness, thirst, vomiting, confusion, muscle weakness, heat sensations on the head or neck, chills and feeling lightheaded (Howe et al., 2007). The severity of each symptom is rated on a graduated scale from 0-10; with anchors, where 0 = no symptoms, 3 = mild symptoms that did not interfere with activity, 5 = moderate symptoms, 7 = severe symptoms necessitating a break and 10 = having to stop work. Overall scores can range between 0 and 110. The higher the score, the greater the severity of heat illness.

Unfortunately, none of these scales and/or indices were used to assess the risk of heat exposure during the archaeology dig in this case study. Only on one occasion was the UV index used, and it was then rated as “too high”. As a result, excavation work in the heat was halted for the day. Use of the WBGT and the HISI might have minimized the heat illness experienced by the present case and could prevent other episodes in the future. Further, individuals who are not acclimatized to work in the heat and in poor physical condition should have gradual exposure to the work when the WBGT is high (Minard et al., 1957).

Preventive measures

Potential measures for the prevention of heat stress include ensuring adequate daily fluid consumption, pre-cooling, acclimatization, choice of light clothing, taking regularly scheduled breaks and heart rate monitoring.

Adequate hydration

The most easily modified risk factor for preventing exertional heat illnesses is hydration. Athletes and other individuals who must work in the heat should start in an euhydrated state (Coris et al., 2004). It is recommended that athletes and workers drink 500 mL 2 hours prior to an event, drink a further 250 mL for every 20 min of physical activity and following intense activity in the heat, they should consume 1300 mL per kilogram of weight loss. For events lasting longer than 1- hr, a mixture of carbohydrates and water can increase intestinal absorption of the fluid consumed. In this case study, the physician recommended a daily consumption of at least 3 L of water. Having a weighing scale at the site to monitor weight loss is a simple but useful measure to ensure adequate fluid replacement.

Cheuvront and Sawka (2005), together with the Gatorade Sports Institute, have developed a mnemonic to help athletes and workers in the heat assess their hydration status: “WUT”, whereby “W” refers to weight, “U” refers to urine and “T” refers to thirst. It is suggested that affected individuals weigh themselves at least daily and that a weight loss of 1 percent of total body weight or more is indicative of dehydration. Confirmation of this would be by examination of urine and presence of thirst. A reduction in urine frequency and darkening of its colour are other indicators of dehydration. Thirst is an indication that dehydration has already developed, with a need to drink.

Pre-cooling

Pre-cooling prior to an athletic event or occupational heat stress is another way to try to ameliorate the effects of heat strain and enhance performance (James et al., 2018). Both internal and external methods of pre-cooling have been proposed. Internal methods consist of ingesting a cool liquid or an ice slurry. External methods include use of cooling vests, cool towels and forearm immersion in cold water. In this case study, the taking of a cold shower prior to excavating helped prolong work time and decreased heat strain as reflected by a reduction in hart rate.

Acclimatization and physical training

Both active and passive heat acclimation strategies have been proposed (Casadio et al., 2017; Coris et al., 2004). For athletes, sport specific heat acclimation is the best tactic when preparing for athletic events in the heat. Pre- or in-season training camps have also been suggested (Casadio et al., 2017), with minimal time required. For example, 60-minute sport-specific exercise training sessions should take place in the heat (30 – 40 °C, 20-60 % relative humidity) for 1 to 2 weeks prior to an event in the heat. Training sessions should be designed to mimic the event, induce high sweat rates and raise core body temperature.

However, access to climatic chambers or travel to environments with higher temperatures is not always practical, and passive acclimatization strategies have also been proposed. Hot tub immersion and sauna exposure are two such methods (Casadio et al., 2017). In untrained individuals, as few as seven, 45-minute hot water baths over a two-week period, can reduce core body temperature and heart rate with subsequent heat exposure. Repeated (3 d) exposure to a sauna (80-100 °C, 10 – 20% relative humidity) can also reduce core temperature during a subsequent heat exposure. For trained individuals, post-exercise hot water immersion or sauna exposure are recommended as a heat acclimation alternative (Casadio et al., 2017). Six exercise sessions (a 40-minute run at 65% $\dot{V}O_{2max}$) followed by hot water baths (40 min at 40 °C) decreased resting, end exercise temperature and increased endurance in the heat. Coris et al. (2004) suggested that 4-7 exercise sessions in the heat, each lasting 1 to 4 hours, are necessary to acclimatize adults adequately.

Lastly, physically fit individuals acclimate to heat exposure much faster than those with a low aerobic capacity (Aoyagi, McLellan, & Shephard, 1997). The number of days required for core body temperature to reach a plateau during a given bout of heat exposure seems directly related to $\dot{V}O_{2max.}$ expressed in mL/kg/min (Pandolf, Burse, & Goldman, 1977). Moreover, highly trained individuals do not seem to gain any benefits from additional heat acclimation (Aoygi, McLellan, & Shephard, 1994). Eight weeks of training (running at 60 – 80% $\dot{V}O_{2max}$ for 30-45 min/d, 3 - 4 d/wk improves aerobic capacity by 16% (Aoygi et al., 1994). When this training program was followed by 6 d of 60 min of heat exposure, there was no difference in the extent of physiological strain as measured by plasma volume, sweat rate and HR. Thus, individuals who are planning to face work in the heat should prepare by participating in an aerobic exercise program at least 8 wk prior to heat exposure.

Regular breaks

Regular breaks should also be scheduled during physical activities in the heat to allow for rest and rehydration. The timing and length of breaks as well as fluid replacement is dependent on which measure of heat stress is used and the intensity of work performed (Luippold et al., 2018). Work to rest ratios based upon WBGT (based upon Fahrenheit readings) are presented on Table 1 and those based upon humidex readings (based upon centigrade temperature measures) are presented in Table 2.

After her immediate recovery, the present case was advised to utilize acclimatization tactics prior to further exposure to unaccustomed elevated ambient temperatures. These same strategies can be used by athletes who need to compete in hot environments (for example, the Tour de France, the Summer Olympics, the FIFA World cup etc).

Irrespective of the means adopted to induce heat adaptations, the physiological and psychological adjustments fall into two categories: 1) short term (4 – 7 d) and 2) moderate term (8 – 14 d or longer) (Casadio et al., 2017). The short-term adaptations include a decrease in core body temperature, a reduction in cardiovascular strain and a decrease in perceived effort. Moderate-term adaptations include an improvement in thermoregulatory function and an enhancement in exercise capacity. Animal models have demonstrated molecular and cellular adaptations including an improvement in the contractile efficiency of the heart and the production of more heat-shock proteins (Casadio et al., 2017).

Conclusions

Exertional heat stress can easily occur in individuals who must work or exercise in a hot environment, with individuals who are un-acclimatized and dehydrated being particularly vulnerable. However, use of tools to assess the severity of heat exposure and an awareness of risk factors and possible symptoms can help in flagging those at risk. Preventive measures (prior heat acclimation, precooling and adequate hydration and rest periods) can also help to decrease the

Table 1: Work to rest ratios based upon WBGT measures.

Heat Category	Temperature (°F)	Light work (250 W)	Moderate Work (425 W)	Heavy Work (600 W)
		Work: Rest Ratio (min)	Work: Rest Ratio (min)	Work: Rest Ratio (min)
1. White	78.0 – 81.9	–	–	40: 20
2. Green	82.0 – 84.9	–	50: 10	30: 30
3. Yellow	85.0 – 87.9	–	40: 20	30: 30
4. Red	88.0 - 89.9	–	30: 30	20: 40
5. Black	>90	50: 10	20: 40	10: 30
Based upon data presented by Luippold et al. (2018)				

risk and severity of heat-related incidents.

Table 2: Work to rest ratios based upon humidex readings.

Humidex Readings	Work: Rest Ratio (min)
38 – 39	45: 15
40 – 41	30: 30
42 – 44	15: 45
45 +	Hazardous to continue activity. Stop activity.

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Author's Qualifications

The author's qualifications are as follows: Ingrid K. M. Brenner: B.P.H.E., B.Sc., B.Sc.N., RN., M.Sc., Ph.D. (Toronto), Ph.D. (Queen's). Roy J. Shephard: C.M., Ph.D., M.B.B.S., M.D. [Lond.], D.P.E., LL.D., D.Sc., FACSM, FCSEP, FFIMS, FAAPE.

References

Amberg, G. C., & Navedo, M. F. (2013). Calcium dynamics in vascular smooth muscle. *Microcirculation, 20*(4), 281-289. doi:10.1111/micc.12046

Aoyagi, Y., McLellan, T. M., & Shephard, R. J. (1997). Interactions of physical training and heat acclimation. The thermophysiology of exercising in a hot environment. *Sports Medicine, 23*(3), 173-210.

Aoygi, Y., McLellan, T. M., & Shephard, R. J. (1994). Effect of training and acclimation on heat tolerance on exercising men wearing protctive clothing. *Eur J Appl Physiol, 68*, 234-245.

Arbury, S., Lindsley, M., & Hodgson, M. (2016). A critical review of OSHA heat enforcement cases. Lessons learned. *Journal of Occupational and Environmental Medicine, 58*(4), 359-363.

Brenner, I., Shek, P. N., Zamecnik, J., & Shephard, R. J. (1998). Autonomic regulation of the circulation during exercise and heat exposure: inferences from heart rate variability. *Sports Medicine, 26*, 85-99.

Carpenter, A. J., & Nunneley, S. A. (1988). Endogenous hormones subtly alter women's response to heat stress. *J Appl Physiol, 65*(5), 2313-2317.

Carter III, R., Cheuvront, S. N., Williams, J. O., Kolka, M. A., Stephenson, L. A., Sawka, M. N., & Amoroso, P. J. (2005). Epidemiology of hospitalizations and deaths from heat illness in soldiers. *Med. Sci. Sports Exerc., 37*(8), 1338-1344.

Casa, D. J., Demartini, J. K., Bergeron, M. F., Csillan, D., Eichner, R., Lopez, R. M., . . . Yeargin, S. W. (2015). National athletic trainers' association position statement: exertional heat illnesses. *Journal of Athletic Training, 50*(9), 986-1000.

Casadio, J. R., Kilding, A. E., Cotter, J. D., & Laursen, P. B. (2017). From lab to real world: heat acclimation considerations for elite athletes. *Sports Medicine, 47*, 1467-1476.

Cheuvront, S. N., & Sawka, M. N. (2005). Hydration assessment of athletes. *Sports Science Exchange, 18*(2), 1 - 13.

Coris, E. E., Ramirez, A. M., & Van Durme, D. J. (2004). Heat illness in athletes. The dangerous combination of heat, humidity and exercise. *Sports Medicine, 34*(1), 1-7.

Drinkwater, B. L., & Horvath, S. M. (1979). Heat tolerance and aging. *Medicine and Science in Sports, 11*(1), 49-55.

Eisenberg, J., & Metthner, M. (2014). *Evaluation of heat stress, heat strain, and rhabdomyolysis in park employees*. Retrieved from: https://stacks.cdc.gov/view/cdc/24083

Hargreaves, M. (2008). Physiological limits to exercise performance in the heat. *Journal of Science and Medicine in Sport, 11*, 66-71. doi:10.1016/j.jsams.2007.07.002

Howe, A. S., & Boden, B. P. (2007). Heat-related illness in athletes. *American Journal of Sports Medicine, 35*(8), 1384-1395. doi:10.1177/0363546507305013

James, C. A., Richardson, A. J., Watt, P. W., Willmott, A. G. B., Gibson, O. R., & Maxwell, N. S. (2018). Short-term heat acclimation and precooling independently and combined, improve 5-km time trial performance on the heat. *Journal of Strength and Conditoning Research, 32*(5), 1366-1375.

Kolka, M. A., & Stephenson, L. A. (1989). Control of sweating during the human menstrual cycle. *Eur J Appl Physiol Occup Physiol, 58*(8), 890-895.

Lapides, J., Bourne, R. B., & Maclean, L. R. (1965). Clinical signs of dehydration and extracellular fluid loss. *JAMA, 191*(5), 141-143.

Luippold, A. J., Charkoudian, N., Kenefick, R. W., Montain, S. J., Lee, J. K. W., Teo, Y. S., & Cheuvront, S. N. (2018). Update: Efficacy of military fluid intake guidance. *Military Medicine, 183*(9/10), e338-e342.

Lyashko, V. N., Vikulova, V. K., Chernicov, V. G., Ivanov, V. I., Ulmasov, K. A., Zatsepina, O. G., & Evgen'ev, M. B. (1994). Comparison of the heat shock response in ethnically and ecologically different human populations. *Proc. Natl. Acad. Sci., 91*, 12492-12495.

McLellan, T. M., Cheung S. S., Latzka, W. A., Sawka, M. N., Pandolf, K. B., Millard, C. E., & Withey, W. R. (1999). Effects of dehydration, hypohydration, and hyperhydration on tolerance during uncompensable heat stress. *Can. J. Appl. Physiol, 24*(4), 349-361.

Merkel, D. L., & Molony, J. R. (2012). Medical sports injuries in the youth athlete: emergency managment. *The International Journal of Sports Physical Therapy, 7*(2), 242-251.

Methner, M., & Eisenberg, J. (2018). Evaluation of heat stress and heat strain among employees working outdoors in an extremely hot environment. *Journal of Occupational and Environmental Hygiene, 15*(6), 474-480. doi:10.1080/15459624.2018.1456663

Minard, D., Belding, H. S., & Kingston, J. R. (1957). Prevention of heat casualties. *JAMA, 165*(14), 1813-1818.

Nerbass, F. B., Pecoits-Filho, R., Clark, Sontrop J. M., McIntyre, C. W., & Moist, L. (2017). Occupational heat stress and kidney health: from farms to factories. *Kidney International Reports, 2*(6), 998-1008. doi: 10.1016/j.ekir.2017.08.012

Pandolf, K. B., Burse, R. L., & Goldman, R. F. (1977). Role of physical fitness in heat acclimatisation, decay and reinduction. *Ergonomics, 20*, 399-408.

Relf, R., Willmott, A., Mee, J., Gibson, O., Saunders, A., Hayes, M., & Maxwell N. (2018). Females exposed to 24 h of sleep deprivation do not experience greater physiological strain, but do perceive heat illness symptoms more severely, during exercise-heat stress. *Journal of Sport Sciences, 36*(3), 348-355. https://doi.org/10.1080/02640414.2017.1306652

Shimizu, M., Kinoshita, K., Hattori, K., Ota, Y., Kanai, T., Kobayashi, H., & Tokuda, Y. (2012). Physical signs of dehydration in the elderly. *Internal Medicine, 51*, 1207-1210.

Taylor, N. A. S. (2014). Human heat adaptation. *Compr Physiol, 4*, 325-365.

Tenaglia, S. A., McLellan, T. M., & Klentrou, P. P. (1999). Influence of menstrual cycle and oral contraceptives on tolerance to uncompensable heat stress. *Eur J Appl Physiol Occup Physiol, 80*(2), 76-83.

Webber, R. C. W., Franz, R. M., Marx, W. M., & Schitte, P. C. (2003). Stress indices, standards and limits with reference to ultra deep mining. *The Journal of the South African Institute of Mining and Metallurgy, June*, 313-324.