ARTICLE

Cold Water Immersion: The Gold Standard for Exertional Heatstroke Treatment

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The key to maximize the chances of surviving exertional heatstroke is rapidly decreasing the elevated core body temperature. Many methods exist to cool the body, but current evidence strongly supports the use of cold water. Preferably, the athlete should be immersed in cold water. If lack of equipment or staff prevents immersion, a continual dousing with cold water provides an effective cooling modality. We refute the many criticisms of this treatment and provide scientific evidence supporting cold water immersion for exertional heatstroke. **Key Words:** hyperthermia, heat illness, cooling rates, exercise, thermoregulation

INTRODUCTION/HISTORICAL PERSPECTIVE

> …"*BUT SUNSTROKE GIVES NO SUCH WARNING. IT STRIKES DOWN ITS VICTIM WITH HIS FULL ARMOR ON. YOUTH, HEALTH, AND STRENGTH OPPOSE NO OBSTACLE TO ITS POWER; NAY, IT WOULD SEEM, IN SOME INSTANCES, TO SEEK OUT SUCH AS THESE, AS IF BOLDLY TO FLAUNT ITS POWER, AND IN THE VERY GLARE OF DAY TO DEAL ITS FINAL BLOW.*"

From Levick J.J., Remarks on sunstroke. *Am. J. Med.* 37:43, 1859.

Exertional heatstroke (EHS) is a potentially lethal outcome for any athlete, laborer, soldier, or other individual who participates in physical activity in warm or hot conditions. Although the condition is relatively rare, its incidence rate is as high as 1 in 1000 at some athletic events (8). Because these events often include 10,000 or more participants, the event medical staff may treat 10 or more cases of EHS. This medical emergency requires extensive logistical planning to assure optimal onsite treatment.

Heatstroke is not new to the medical community (5). In 24 B.C., Roman soldiers with heatstroke were instructed to drink olive oil and wine while rubbing both liquids on the body (18). In the 1500s, physicians recommended stimulating friction and bloodletting to "release the heat" (27). In the 18th century, the cause of heatstroke was once thought to be drinking cold water. Patients would receive the diagnosis of "hurt by drinking cold water." Amazingly, public pumps were posted with signs warning about the risk of sudden death from drinking cold water (27).

Recently (in a historical sense, *i.e.*, 50 to 100 yrs or so ago), a widely circulated opinion has encouraged some in the medical community to avoid using cold water immersion (CWI) for the acute treatment of heatstroke (19,30). This line of thinking has reached the medical community, including athletic trainers, team physicians, emergency department physicians, emergency medical technicians, registered nurses, first aid–trained coaches, and others. The number one criticism of CWI is that patients will actually heat up (or at least not cool down) in CWI because of peripheral vasoconstriction (PVC) and shivering. However, scientific evidence strongly refutes this criticism. Evidence from basic physiological studies looking at the effect of CWI on cooling rates in hyperthermic individuals and treatment of actual EHS victims clearly shows that CWI has cooling rates superior to any other known modality (2,10,11,21,22).

We have recently stated, "it is quite difficult, if not impossible, to kill an otherwise healthy athlete experiencing EHS if rapid cooling via cold/ice water immersion is implemented within a few minutes after collapse" (9). Any delay in the process of rapidly cooling an individual experiencing

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EHS, whether it is caused by a delay in the initiation of treatment or the use of an inferior coding modality, can dramatically increase the likelihood of morbidity and mortality associated with the condition.

The hypothesis to be presented in this article is that CWI should be the preferred method of treatment of EHS because of superior cooling rates and unsurpassed survival rates. Hence, additionally, this review aims to conclusively refute the myth that CWI hinders cooling of hyperthermic athletes because of PVC and shivering. Protocols regarding the treatment of EHS should be in accordance with best practices.

PHYSIOLOGY OF CWI

Basic Dynamics and Cooling Capacity of Humans in Water

Water has many physical characteristics that differentiate it from air, helping to explain the powerful cooling that occurs when an athlete with EHS is treated with CWI. For example, water has a thermal conductivity of 630.5 mW/m^2 per °K, whereas air is only 26.2 mW/m^2 per °K. This 24-fold greater capacity for thermal conductivity translates into a much greater potential for heat transfer (15,29). Given that in water, the immersed portion has a surface area that is nearly 100% in direct contact with water that surrounds it, the conductive potential is enormous and far superior to air. In addition, the specific heat of water is 4.2 J/g per °K compared with 1.0 J/g per °K for air, and the density of water is 0.9922 g/cm^3 compared with 0.0012 g/cm^3 for air. The resulting volume-specific heat capacity of water is nearly 3500 times greater than that of air (15,29). Thus, a person cools four times faster in water than in air of the same temperature (15). To put it another way, water provides the same cooling capacity as air that is 11°C (20°F) cooler (15). These principles of the cooling capacity of water apply when a normothermic person is subjected to cold water (as in the case of a person initially capsized in the north Atlantic) and to a hyperthermic individual (from EHS or illness). The initial physiological responses to the cold water are different (10,12,15,22,23,29). A normothermic person defends body temperature via PVC and shivering (discussed later), whereas a hyperthermic individual blunts these responses so as to cool rapidly (as noted by the immediate drop in temperature, compared with a short period of maintenance for a normorthermic person when both are subjected to CWI).

Peripheral/Central Control of Body Temperature

The degree of PVC and shivering that occurs for an individual during CWI is dictated by the current state of the peripheral and central receptors for body temperature regulation. A great proportion (some have speculated approximately a 9:1 ratio when considering sweat production) of the response is regulated by changes in core body temperature via sensors in the hypothalamus (25). The remainder of the response is determined by skin temperature. In other words, a 1°C (1.8°F) change in core body temperature elicits an approximately nine-fold greater thermoregulatory response than a 1°C (1.8°F) change in skin temperature (25). Obviously, skin temperature fluctuates more rapidly and across a greater range of temperatures than core body temperature during daily living (25). The sensitivity of the responses to fluctuations in skin temperature helps to generate rapid changes in skin blood flow, sweating, and shivering, depending on the change in skin temperature which is influenced by the temperature of the surrounding environment, the degree of skin exposed, exercise, etc.

In EHS, the large change in core body temperature (approximately 5°C/10°F higher than at rest) provides a powerful influence that can partially or completely negate the influence of CWI on lowering skin temperature and the resultant PVC and shivering. Although PVC and shivering likely happen to some degree, the rapid cooling seen in a severely hyperthermic person in CWI shows that the central responses are quite different than initially in a normothermic individual during CWI. In addition, given the powerful cooling that eventually occurs (beginning after about 20 min) for a normothermic individual, the magnitude of thermal conductivity and convection of moving water over the entire body surface shows that adequate perfusion (shunted away because of PVC) may not be necessary to extract the heat of the body in a rapid manner and that these processes can overpower the heat preserved via PVC or shivering (15,22).

TREATMENT OF EHS

Overwhelming evidence indicates that the amount of time that rectal temperature exceeds a critical threshold temperature for cell damage dictates the severity of EHS injury (4,13,17,24,28). Lowering the core body temperature to less than 40°C (104°C) within 30 min should be the primary goal of EHS treatment (1,7). Optimal treatment begins with rapid and accurate assessment because minimal time will be lost in the process of initiating cooling (1,3,7–9,28). This explains why rectal temperature must be done on-site and why the medical provider cannot rely on inaccurate modes of assessing core temperature (*i.e.*, tympanic/aural, oral, temporal, axillary sites) (1,3,7–9,28).

The window of opportunity to provide immediate cooling postcollapse is narrow and must be done with a modality that has sufficient cooling potential (8). The clinician also must consider which cooling modalities are feasible and optimal for each particular circumstance. The literature indicates that the care provider should use CWI unless a reason exists to use another cooling technique. The clinician also should consider the logistics of moving an athlete into and out of a tub; maintenance of the airway, breathing and circulation; and monitoring of temperature measurements.

Physiological Issues Related to Hyperthermia and EHS

Gaffin and Hubbard (13) eloquently describe a cascade of events that may occur when homeostasis is impaired because of sustained and severe hyperthermia during EHS.

An examination of their model for the physiology and pathophysiology of heat stress and heatstroke provides rationale for the multisystem organ damage that commonly afflicts those who are not rapidly cooled. After the onset of cell destruction extensive enough to cause organ damage or failure, the prognosis worsens. This cascade of events causes most EHS deaths to occur during the 12-h to 1-wk period after EHS. It is quite rare for an EHS patient to succumb in the few hours after the incident, but the action taken in this period will dictate the degree of cell damage that will either lead to recovery or spiral toward catastrophic organ deterioration (1,3,7–9,13).

Effectiveness of Different Cooling Modalities (Cooling Rates)

Extensive evaluations of cooling rates associated with various cooling modalities have been previously published (9,17,26). Not all studies are truly comparable because of methodological differences that influence the cooling rates. These differences include questions such as:

- Was the patients experiencing EHS or acute hyperthermia?
- Was the condition classic heatstroke or EHS?
- Specifics regarding the cooling process (What were the core body temperature starting and ending points? What was the specific technique? Was the entire body immersed or only the torso? Was the water circulated? What was the water temperature? Was the subject exercising? What are the subjects' body fat percent?, etc.).

The effectiveness of a wide variety of cooling modalities are compared in Figure 1 (9). This figure shows the superior cooling rates documented in water immersion studies. Other modes of cooling also may be effective, including that used by the Israeli military: a combination of spraying moderate-temperature water plus rapid air movement provided by a fan. This form of cooling encourages evaporative and convective cooling with good results (16). In addition, medical staffs at the Twin Cities Marathon, Marine Corps Marathon, and Quantico Marine Base have placed cold, wet towels over the entire body and/or continuously doused with cold water and placed ice packs on peripheral arteries (and massaging the limbs with ice bags in some situations). This method results in cooling rates that are 2/3 to 3/4 as fast as CWI, and because medical care begins immediately, survival rates are excellent (20). Medical staff should also consider cold showers or dousing athletes with cold water from a hose when CWI is not possible.

The cooling rate of ice bags on the peripheral arteries (about 0.03°C/min [0.05°F/min]), one example of an inferior cooling method (see Fig. 1), causes the area under the curve (*i.e.*, time vs rectal temperature) to be large and increases the likelihood of tissue and organ injury (Fig. 2). We do not recommend a modality that provides cooling of less than 0.1°C/min (0.18°F/min) when cooling begins immediately, and not less than 0.15°C/min (0.27°F/min) if cooling is delayed longer than 20–30 min after collapse (*i.e.*, only CWI).

The key element is that cooling is initiated as soon as possible after the onset of the condition. Many modes can

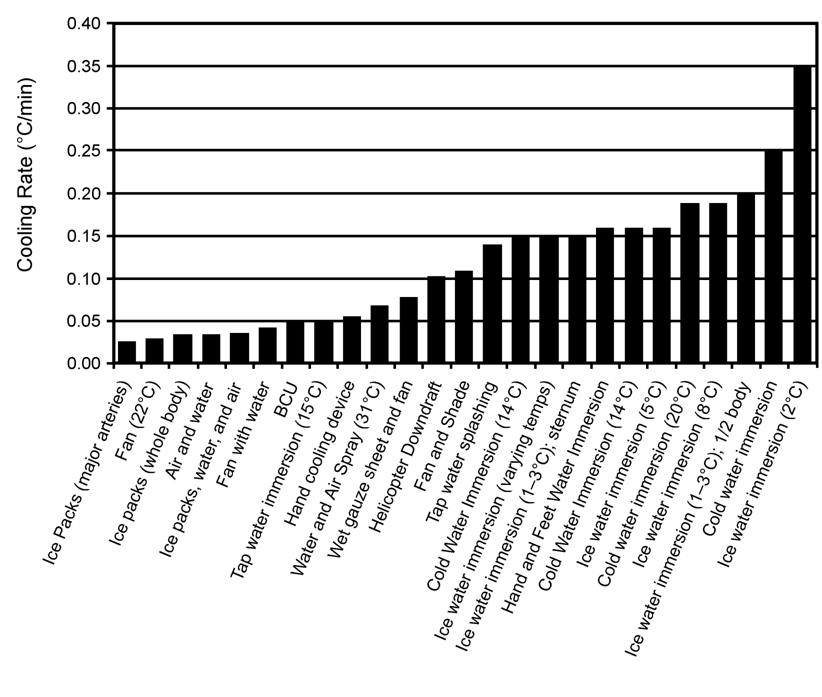

Figure 1. Cooling rates associated with various modalities. Figure depicts experiments with healthy hyperthermic athletes and heatstroke victims. Reference's are associated with original article. (Reprinted with permission from Casa, D.J., L.E. Armstrong, M.S. Ganio, and S.W. Yeargin. Exertional heat stroke in competitive athletes. *Curr. Sports Med. Rep*. 4:309–317, 2005. Copyright © 2005 Current Medicine Group, LLC. Used with permission.)

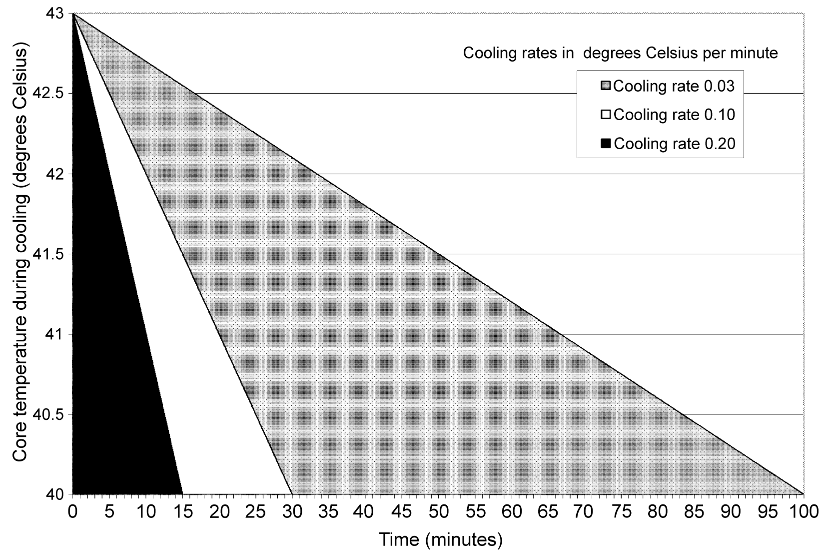

Figure 2. Area under the curve for three cooling rates. The graph is a representation of expected core temperature decrease of an exertional heatstroke (EHS) victim who exhibits a characteristic starting temperature of 43°C (109°F). The end point has been standardized here as a body temperature of 40°C (104°F), which is just below a likely threshold for reduced risk of cell damage. Cooling rates from the typical starting temperature to the set hypothetical standard of 40°C are in units of °C per minute. The area under each curve represents cumulative time a patient may spend above the threshold temperature of 40°C during cooling. The assumptions in assembling this theoretical image include: (1) constant cooling rate (cooling rates are known to fluctuate, but average cooling rate is used here, may represent the best estimate of a relative °C per minute comparison); (2) initial temperature (43°C) is the same in all conditions; (3) initiation of treatment relative to diagnosis and onset is the same for all conditions; and (4) conditions represent average individual with similar thermal response capacities.

accomplish this goal. Ultimately though, the best cooling rates reported in the literature are with CWI, which consistently provides outstanding cooling rates in both controlled studies and clinical interventions of EHS patients (2,10,11,17,22,26). Proulx *et al.* (22) probably offered the single greatest this field as the first to combine certain techniques in a controlled setting, producing the fastest known cooling rate in the scientific literature. They immersed subjects in various water temperatures under controlled conditions (the only thing different was the temperature of the water bath), including immersing the entire body (except the head), stirring the water, and previous exercise to heat up to 40°C (104°F). The four water temperatures between 2°C (36°F) and 20°C (68°F) all provided excellent cooling rates (greater than 0.2°C/min for the decline from 40°C to 38°C), but the cooling rate of the 2°C bath (0.39°C/min for the decline from 40°C to 38°C) was nearly twice that of the other temperatures (22). This rate translates into approximately a 4°F drop in 5–6 min, a staggering testament to the cooling potential of immersion in moving water! Although the subjects did not experience EHS but induced hyperthermia, the physiological influence of cold water as a cooling modality remains relevant. Others have provided additional evidence of the powerful influence of cold water on cooling of actual EHS patients (2,6,11,20).

The goal is not to criticize or even question non-CWI cooling modalities that are effective in rapidly cooling EHS patients. Many are suitable and successful (16,20). Our goal is to refute the myth that CWI hinders cooling and to show that CWI actually has outstanding cooling and survival rates. Because of its negligible cost and the relative ease and availability in controlled athletic and many military training (*i.e.*, basic training) settings, and superior cooling effectiveness, CWI should be the preferred cooling method in most circumstances. Some wartime situations, remote athletic events, and other specific circumstances may preclude its use, but these are the exceptions rather than the rule. In addition, the survival rates resulting from the above mentioned alternatives are impressive, but CWI initiated right after the onset of symptoms is believed to have a survival rate that is nearly (or perhaps actually) 100% (6,11).

MISCONCEPTIONS ABOUT USING CWI FOR THE TREATMENT OF EHS

Numerous reasons have been cited for not using CWI to treat EHS. Table 1 provides examples from the medical literature of explanations/reasons why CWI should not be used for the rapid cooling of hyperthermic individuals. Our goal in this section is to refute these misconceptions.

Peripheral Vasoconstriction

This assertion states that CWI induces PVC in hyperthermic athletes, which shunts warm blood away from the surface of the body and impedes cooling via convection and conduction. The speculation continues that the hyperthermic athlete may even "heat up" because the heat has nowhere to go. Wyndham *et al.* (30) are likely one of the sources of this assertion. The results of their classic study indicated inferior cooling rates for CWI. The reasons are not completely understood, however, because no subsequent

TABLE 1. Common misconceptions regarding the use of CWI to treat hyperthermic individuals.

Misconceptions	Explanations to Perpetuate Misconception
Peripheral vasoconstriction delays cooling	Cold-induced dermal vasoconstriction may impede heat dissipation, even to the extent of effectively insulating the body core from its surrounding environment[f]
	Intense peripheral vasoconstriction shunting blood away from the skin and perhaps causing a paradoxic increase in core temperature[d]
	The rapid cooling of the skin from immersion in ice water induces shivering and causes intense vasoconstriction of the cutaneous vessels, which impedes the transfer of heat from the body core to the surface, which is an important process in eliminating the heat load[i]
	Common sense dictates that an overheated athlete should be placed in a cool environment, such as an air-conditioned room or even an ice bath. However, this can be counterproductive and even dangerous. The cold stimulus on the skin causes blood vessels in the skin to constrict, preventing heat dissipation from the body core.[g]
	…It is necessary to emphasize the elementary fact that the evaporation of fluid from the body surface is quantitatively the most important avenue of heat dissipation. All primary efforts should therefore be directed towards achieving this goal, *e.g.*, by means of compressed air, fans and concurrent maintenance of a wetted body surface. The use of ice packs, chilled water, or ice-baths is contraindicated for the simple reason that they are more likely to induce dermal vasoconstriction, an event tantamount to insulating the hot body core from its environment, than to achieve heat dissipation through conduction[h]
Shivering delays cooling	Cold water immersion and cooling blankets can also induce shivering and cutaneous vasoconstriction, which may lead to an undesirable increase in core body temperature[b]
	Early immersion in ice water, though frequently recommended, is not without hazard, for it causes a sudden drop in temperature, and the resultant vasoconstriction and shivering impede further heat loss.[c]
Immersion is uncomfortable for patient/staff	Cold water immersion is uncomfortable for both patient and staff and can interfere with the resuscitation measures that are often necessary in this setting[b]
	In contrast to the severe discomfort, including shivering, observed by whole body immersion in an ice water bath, the patient is comfortable and at ease (with the body cooling unit).[f]
Difficult to apply supplemental treatments (AED, intravenous fluid, oxygen, etc.)	Although thermal vasoconstriction may be countered through whole-body immersion in lukewarm water, immersion techniques have other disadvantages, *e.g.*, they are impractical if administration of oxygen and intravenous fluids is necessary…[e] Immersion cooling also may make it difficult to access a patient—a concern if the patient experiences cardiac arrest—…[a]
Immersion may be unsanitary	Immersion in ice water is uncomfortable, unpleasant, and unclean for comatose or restless patients who may vomit or urinate during cooling[i]
	…While a tub of water mixed with vomitus and diarrhoea of comatose patients in unhygienic to both the patient and his attendants[e]
Hypothermic afterdrop	The method is nevertheless contraindicated, apart from the difficulty of patient management and discomfort, simply on the basis of the danger of a hypothermic overshoot.[f]
Immersion is not the most effective or recommended cooling modality	The results reported here suggest that evaporative cooling (tap water splashing with wind) is the preferred procedure on several counts. (Also refute immersion simply on the basis of the danger of a hypothermic overshoot[f])
	The device can extract heat 3–5 times faster than any other technique that is available today for extracting heat. The system is believed to be better than cooling off with a bucket of ice[g]
Immersion is unfeasible and requires staffing numbers	How can one medical professional safely immerse an individual in a tub of water?

[a]Glazer, J.L. Management of heat stroke and heat exhaustion. *Am. Fam. Physician.* 71:2113–2140, 2141–2142, 2005.

[b]Graham, B.S. Features and outcomes of classic heat stroke [letter to the editor]. *Ann. Int. Med.* 130:613–614, 1999.

[c]Hart, L.E., B.P. Egier, A.G. Shimizu, P.J. Tandan, and J.R. Sutton. Exertional heat stroke: the runner's nemesis. CMAJ 122:1144–1149, 1980.

[d]Khogali M. Evaluation and treatment of heat-related illnesses [letters to the editor]. *Am Fam Physician.* 67(7):1440, 2003.

[e]Kielblock, A.J., J.P. Van Rensburg, and R.M. Franz. Body cooling as a method for reducing hyperthermia: an evaluation of techniques. *S. Afr. Med. J.* 69:378–380, 1986.

[f]Kielblock, A.J. Strategies for the prevention of heat disorders with particular reference to the efficacy of body cooling procedures. In: *Heat Stress: Physical Exertion and Environment*, J.R.S. Hales and D.A.B. Richerds (Eds.). Amsterdam: Elsevier Science Publishers B.V., 1987, pp. 489–498.

[g]Muller, J. Device cools athletes from the inside out. ABC News. http://abcnews.go.com/technology/weather/story%3Fid%3D97563page%3D1. Accessed April 6, 2006. And AVAcore RTX™ published marketing brochure materials AVAcore Technologies, Inc., Palo Alto, CA, 2004.

[h]Strydom, N.B., A.J. Kielblock, P.C. Schutte. Heatstroke, it's definition, diagnosis, and treatment. *S. Afr. Med. J.* 61:537, 1982.

[i]Yaqub., B, and S.A. Deeb. Heat strokes: aetiopathogenesis, neurological characteristics, treatment, and outcome. *J. Neurol. Sci.* 156:144–151, 1998.

CWI indicates cold water immersion.

study reported similar results. We do not dispute that PVC occurs during CWI. Cold water immersion, despite PVC, provides great conductive and convective thermal transfer so that body organs cool rapidly (15).

We do not argue against PVC occuring in a normothermic person immersed in cold water or even the possibility that some PVC occurs when a severely hyperthermic athlete is placed in cold water (15,29). The most relevant point has to do with the notion that the PVC somehow prevents rapid cooling from occurring. We are not aware of any severely hyperthermic athlete who has been placed in CWI and not demonstrated rapid cooling.

In great measure, the thermoregulatory response to heat is dictated by the hypothalamus and the temperature it perceives from the core, whereas a lesser portion is influenced by the skin temperature. The evidence supports this notion: cooling rates of hyperthermic individuals during CWI are consistently reported to be about 0.16–0.2°C/min (0.29–0.36°F/min) or upward of 0.35°C/min (0.63°F/min) when multiple elements that influence cooling rates are in place: circulating the water, immersing the entire body except the head, previous exercise, thin stature) (2,10,11,22). Conversely, a normothermic person who is placed in cold water shows no change or a slight (0.1–0.2°C [0.18–0.36°F]) increase in core body temperature (the Currie response; see (Fig. 3)) during the first 8 to 10 min because of the combination of PVC and shivering (12,15,23). For most normothermic individuals, core body temperature can be preserved for about 15–20 min from the beginning of CWI, but then the temperature begins to fall rapidly as the body can no longer provide enough stimulus to offset the powerful cooling capacity of water (15,23). The rapid cooling is why survivors of capsized boats, downed planes, or people who fall through the ice experience miserably debilitating hypothermia in less than an hour in most cold water situations (assuming no wet suits, average body fat). These individuals have a typical physiological response that provides short-term protection of body temperature and then an inevitable succumbing to the elements (15). The Currie response was noted in 1798 (12), when some of the first experiments with humans and water (both cold and hot) immersion were conducted. The misinterpretation of this physiological response (the lack of body temperature drop when initially placed in cold water and maybe even a very slight paradoxical increase in core temperature Fig. 3) has been largely caused by the notion that this information was assumed to be true for all humans in cold water (Table 1). This is simply not the case. The typical response for those who have collected data on cooling rates of severely hyperthermic individuals during CWI immediately postexercise is a rapid cooling rate. This finding speaks to the difference in the thermoregulatory response for normothermic and hyperthermic individuals when subjected to CWI. This is the crux of the argument in favor of CWI for the acute treatment of EHS. In addition, it is also at the core of debunking the principal reason provided to not use CWI (Table 1).

The misinterpretation of the Currie response (see Fig. 3) has caused many medical professionals to worry about the consequences of no change or a slight increase in body temperature when initially placed in cold water. However, this increase is quite transient, the influence is quite minor (only 0.1–0.2°C [0.18–0.36°F]), and most importantly, it is a normothermic response. When medical professionals see the rising temperatures plotted against time, they may become leery of CWI as a cooling modality for EHS (Table 1, Fig. 3). The message for educational sessions is that the human body in cold water cools rapidly, more quickly in a hyperthermic individual than a normothermic individual, but in both cases the drop is precipitous and powerful.

Shivering

Shivering is an inevitable consequence of falling temperature or the potential for decreasing temperature (*i.e.*, especially skin temperature). An interesting note here is that nearly all normothermic individuals begin to shiver when placed in cold water, yet EHS victims generally do not shiver (unless cooled too long). This emphasizes the integrative role of hypothalamic and skin temperature in regulating shivering (Table 1). In addition, the work of Proulx *et al.* (22) shows the powerful cooling that can occur in hyperthermic individuals (but not EHS), despite the presence of a shivering response.

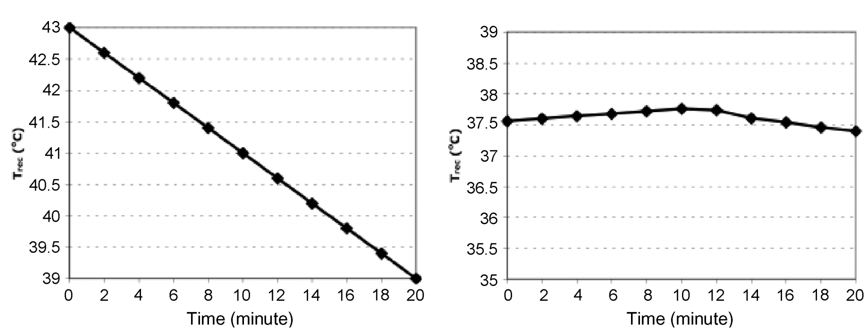

Figure 3. Comparison of responses to cold water immersion for hyperthermic (left panel) and normothermic (right panel) individuals. This figure represents the hypothetical differences in initial response to cold water immersion. Note that the scales are the same, representing 4°C to show the proposed increase in temperature is short-lived and insignificant in a normothermic individual. This figure shows a typical cooling rate of CWI (0.2°C/min) and is not based on actual data points, but is hypothetical based on research studies of exertional heatstroke victims and hyperthermic athletes involving CWI. The temperature of the normothermic individual would begin a precipitous drop beyond approximately 20 min.

Discomfort for Patient or Staff

Some authors have noted that cold water is extremely uncomfortable for the EHS victim and the staff providing care. The physical comfort of the patient or the staff should not be a primary concern during the acute treatment of EHS. Rapid cooling maximizes the likelihood that cell destruction will not occur during this period of extreme hyperthermia. Comfort, although a consideration, should be secondary to delivery of optimal treatment. In addition, we have never received serious complaints from an athlete with EHS about the water temperature (cold water and ice may be quite refreshing for a person who has a body temperature of 43.3°C [110°F]).

Access to Supplemental Treatments

Access to supplemental treatments is the most legitimate concern about CWI, but this is an emergency in which the risks of EHS far outweigh the risks or inconveniences of foregoing supplemental treatments. Administration of oxygen and intravenous fluids is quite feasible during immersion; the mouth and arms are easily accessed. Potential use of an automated external defibrillator (AED) is a greater concern. Fortunately, athletes with EHS who are treated rapidly via aggressive cooling rarely have cardiovascular problems requiring an AED. Cardiac events may be associated with EHS, but these likely occur in individuals who were not recognized or treated rapidly, and who have organ damage at

TABLE 2. Practical guidelines for implementing cold water immersion for an exertional heat stroke patient.

1. Initial responses. Once exertional heat stroke is suspected, prepare to cool the patient and contact emergency medical services (EMS).
2. Preparation of ice water immersion. On the field or in a temporary medical tent, half fill the tub or wading pool with water and ice (before an emergency, check the water source to see how quickly it fills the immersion tub).
   a. The stock tank can be filled with ice and cold water before an event (or have tub half filled with water and 3–4 coolers of ice next to tub, this prevents having to keep tub cold through day).
   b. Ice should cover the surface of the water at all times.
   c. If the athlete collapses near an athletic training room, a whirlpool tub or cold shower may be used.
3. Determination of vital signs. Just before immersing the heat stroke patient, take vital signs.
   a. Assess core body temperature with a rectal thermistor.
   b. Check airway, breathing, pulse, and blood pressure.
   c. Assess the level of central nervous system dysfunction.
4. Beginning ice water immersion. Place the athlete in the ice water immersion tub. Medical staff, volunteers, and teammates may be needed to assist with a smooth and safe entry and exit.
5. Total body coverage. Cover as much of the body as possible with ice water while cooling.
   a. If full body coverage is not possible due to the container, cover the torso as much as possible.
   b. In order to keep the athlete's head and neck above water, an assistant may hold the victim under the axillae with a towel or sheet wrapped across the chest and under the arms.
6. Circulating water. During cooling, water should be continuously circulated to increase the water-to-skin temperature gradient. Have an assistant swirl the water during cooling.
7. Continued medical assessment. Vital signs should be monitored at regular intervals.
   a. It may be helpful for an assistant to stand nearby in case the athlete becomes combative.
   b. Other assistants may be needed to lift or roll the athlete if vomiting occurs.
8. Fluid administration. If a qualified medical professional is available, an intravenous fluid line can be placed for hydration and support of cardiovascular function.
   a. Rest the arm on the side of the water immersion tub.
9. Cooling duration. Continue cooling until the patient's rectal temperature lowers to 39°C (102°F).
   a. If rectal temperature cannot be measured and cold water immersion is indicated, cool for 10–15 minutes and then transport to a medical facility.
   b. If a less effective cooling modality is administered, cool for 25–45 minutes and then transport to a medical facility.
10. Patient transfer. Remove the patient from the immersion tub only after rectal temperature reaches 39°C (102°F) and then transfer to the nearest medical facility via EMS as quickly as possible.
    a. Cooling should be the primary goal before transport. If EMS or the hospital is not equipped to cool via ice water immersion, consider continued cooling to a safe rectal temperature on site.
11. Advanced medical support. During transportation, maintenance of the rectal thermistor allows body temperature to be monitored continuously.
    a. Once the athlete has arrived at the hospital, tests and other treatments will address issues resulting from the hyperthermia.

some point after the initial condition. If AED treatment is required, the athlete should be removed from the tub, the contact points dried, and the process begun (similar to an individual who is pulled from a swimming pool). Some authors speculate that CWI can induce cardiac arrhythmia and have recommended using warmer water with older heatstroke patients (14,16). Our clinical experiences and the existing literature both support the notion that the risk of not cooling aggressively far outweighs the potential risk of cardiac events.

Risk of Drowning

Any athlete who is immersed during the treatment of EHS could be a potential drowning victim. A few precautions should be in place to assure this does not occur:

1. Supervise the athlete continuously.
2. Recruit teammates and colleagues to assist.
3. Use tubs that are designed with ease of entry and exit in mind.
4. To ensure that the head does not go underwater, place a sheet under the armpits of the athlete, and have an assistant stand behind the athlete while holding both ends of the sheet.

Unsanitary Conditions

Some people claim that CWI can cause sanitation issues because of the potential for vomiting or diarrhea. Although this is a distinct possibility during cooling, we believe that a dirty tub is an acceptable tradeoff to a permanently disabled athlete. We recommend buying cleaning products and cleaning the tub after each use in which it becomes apparent this is necessary. A tub with quick drainage, an area for the water to drain, and the ability to quickly refill the tub for the next use are all important considerations.

Hypothermic Afterdrop

Hypothermic afterdrop occurs when an athlete with EHS is cooled excessively and experiences a below normal core body temperature that requires rewarming. This may be of greater concern if hypothalamic control of body temperature is blunted. Such hypothermia (*i.e.*, <36°C [96.8°F]) can be avoided if simple precautions are taken. A flexible rectal thermistor should remain in place during CWI (7). This allows the temperature to be monitored and signals when the patient can be removed from the water bath (*i.e.*, when a rectal temperature of 39°C [102°F] is reached). When using a common inflexible rectal thermometer, a typical CWI cooling rate (*i.e.*, 0.2°C/min [0.36°F/min]) should be used to calculate when the temperature will reach approximately 39°C (102°F). This reduces the number of times that the rectal thermometer needs to be inserted. If rectal temperature cannot be assessed on-site, yet the medical provider is confident of the EHS diagnosis, cooling should be instituted for approximately 15–20 min, using the best clinical judgment as to when to cease cooling therapy.

PRACTICAL CONSIDERATIONS OF CWI

Organizations also encourage rapid cooling via CWI, including the American College of Sports Medicine (1), National Athletic Trainers' Association (3), and the United States Armed Forces (13,14,28). However, these organizations realistically note that ice water and a tub may not always be available to treat an EHS victim, and that other modes of cooling (see above) can be effective if initiated promptly (1,3,13,14,28). Procedural guidelines and considerations for the actual process of assessing, preparing, immersing, removing, transporting, and monitoring an athlete with EHS are provided in Table 2. Research regarding EHS lead us to make the following recommendations:

1. Measure rectal temperature and use clinical judgment regarding central nervous system dysfunction and other signs and symptoms to quickly and accurately determine the patient's condition and whether EHS is occurring (1,3,8,9,14,28).
2. Begin cooling individuals with EHS as rapidly as possible. The concept of "cool first, transport second" is strongly recommended, assuming that properly trained medical professionals, such as athletic trainers or physicians, are present to complete the cooling on-site via CWI (or a suitable alternative modality if CWI is not possible) and then transport to a medical facility. This method eliminates delays in treatment caused by the time constraints of arrival of care, transport, and the possibility that cooling may not be immediate or aggressive at the hospital. This protocol should be discussed with supervisors, colleagues, and adjunct medical personnel before a case of EHS occurs, so that the involved parties are in agreement during the stress of the moment (7). Implementing these recommendations emphasizes in the strongest possible manner the importance of immediate and aggressive cooling and the critical initial 30–60 min after EHS onset.
3. Use a cooling modality that has cooling rates sufficient to lower core temperature to less than 40°C (104°F) within 30 min.
4. Provide fluid intravenously if dehydrated (if adequate staff is available to do so); do this immediately at hospital if not done on-site (1,8,21).
5. Remove from the cooling modality when the rectal temperature reaches 39°C (102°F); then immediately transport to medical facility (or continue to monitor if an adequately staffed on-site medical facility is available).
6. Assure physician supervision after cooling is complete to monitor for sequelae, provide clearance for discharge from the hospital or medical tent, and guide (in conjunction with the athletic trainer) the return-to-participation process (8).

CONCLUSIONS

The key element in maximizing the chances of surviving EHS is rapidly decreasing the elevated core body temperature. Many methods exist to cool the body, but the evidence currently available provides strong support that cold water, preferably immersion, or if lack of equipment or staff warrant, a continual dousing of cold water (as would occur in a cold shower or with ice water–soaked towels), provides the fastest cooling rate. We have refuted the repeated criticisms of using

CWI to treat EHS. The bottom line is that the powerful cooling capacity provided by cold water offers the best opportunity for an otherwise healthy athlete who experiences EHS to survive the incident and experience no lasting consequences.

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