Body Bag Cooling with Two Different Water Temperatures for the Treatment of Hyperthermia

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INTRODUCTION: Exertional heatstroke (EHS) is a life-threatening condition that requires quick recognition and cooling for survival. Experts recommend using cooling modalities that reduce rectal temperature (T_{REC}) faster than 0.16°C/min though rates above 0.08°C/min are considered "acceptable." Hyperthermic individuals treated in body bags filled with ice water (~3°C) have excellent cooling rates (0.28 ± 0.09°C/min). However, clinicians may not have access to large amounts of ice or ice water when treating EHS victims. The purpose of this study was to determine if using a body bag filled with water near the upper limits of expert recommendations for EHS treatment would produce acceptable (>0.08°C/min) or "ideal (>0.16°C/min)" T_{REC} cooling rates or different nadir values.

METHODS: A total of 12 individuals (9 men, 3 women; age: 21 ± 2 yr; mass: 74.6 ± 10.2 kg; height: 179.5 ± 9.6 cm) exercised in the heat until T_{REC} was 39.5°C. They lay supine while 211.4 ± 19.5 L of 10°C (Ten) or 15°C (Fifteen) water was poured into a body bag. Subjects cooled until T_{REC} was 38°C. They exited the body bag and rested in the heat for 10 min.

RESULTS: Subjects exercised in similar conditions and for similar durations (Ten = 46.3 ± 8.6 min, Fifteen = 46.2 ± 7.8 min). T_{REC} cooling rates were faster in Ten than Fifteen (Ten = 0.18 ± 0.07°C/min, Fifteen = 0.14 ± 0.09°C/min). T_{REC} nadir was slightly higher in Fifteen (37.3 ± 0.2°C) than Ten (37.1 ± 0.3°C).

DISCUSSION: Body bag cooling rates met expert definitions of acceptable (Fifteen) and ideal (Ten) for EHS treatment. This information is valuable for clinicians who do not have access to or the resources for ice water cooling to treat EHS.

KEYWORDS: exertional heat stroke, Polar Life Pod, portability, rectal temperature.

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Rapid recognition and whole-body cooling is critical to reduce exertional heatstroke (EHS) morbidity and mortality.[2,3,5] Fortunately, many tools are available to perform cold water immersion (CWI) in the field and range from stationary tubs/pools[25] to more portable options like tarp-assisted cooling with oscillation (TACO).[7,11] Having portable CWI methods are important because some of these tools are relatively inexpensive and provide the clinician options to treat EHS in a variety of terrains and locations. Some expert pronouncements[2,14] recommend immersing EHS patients up to the neck in water between 1.7°C and 15°C with the goal being to have "acceptable" or "ideal" cooling rates during treatment (0.08°C/min to 0.15°C/min or >0.16°C/min, respectively).[12]

Recently, Miller and Amaria[13] demonstrated body bag cooling with a device called the Polar Life Pod® (Polar Products, Inc; Stow, OH, United States) was effective at treating exercise-induced hyperthermia. The cooling rates were excellent (0.28 ± 0.09°C/min) when 152 L to 227 L (40 to 60 gal) of ice water (~3°C) were used and similar to those from the stationary tubs frequently used in the field to treat EHS patients.[3,25] Unfortunately, using ice water in the body bag also produced significant rectal temperature (T_{REC}) afterdrop and low T_{REC} nadir.[13] This could potentially lead to overcooling and hypothermia and necessitate rewarming procedures. While experts[2,20] often recommend using ice water when treating EHS, some clinicians may not have access to large amounts of ice or ice water. Moreover, ice water initially prepared and reserved for use in

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emergency situations may increase in temperature if exposed to hot and humid environmental conditions over time, thereby reducing the thermal gradient when used to treat an EHS victim.

When hyperthermic humans are immersed in stationary tubs filled with warmer water (10–26°C), authors have observed lower, but still acceptable T_{REC} cooling rates.[16,17,23] However, these authors[16,17,23] used water volumes considerably larger than is possible with body bag cooling. Determining the cooling efficacy of body bags with water temperatures at the high end of expert recommendations[2] is crucial because not all clinicians have access to large volumes of ice or ice water in emergency settings. To our knowledge, no one has examined whether cold or cool water placed in body bags results in cooling rates consistent with EHS survivability.

The purpose of this study was twofold. First, we questioned whether 10°C (Ten) or 15°C (Fifteen) water used in body bags would reduce T_{REC} at "acceptable" or "ideal" rates.[12] Second, we determined if T_{REC} cooling rates differed between water temperatures or had different nadir values. We hypothesized T_{REC} cooling rates and nadir values would differ between water temperatures, be acceptable with Fifteen, and ideal with Ten.

Table I. Subject Demographics and Hydration Information.

DEMOGRAPHIC/HYDRATION INFORMATION	TEN	FIFTEEN
Demographics		
Age (yr)	21 ± 2	
Men and women (N)	9 and 3	
Body mass index	23 ± 3	
Body fat (%)	11 ± 8	
Body surface area (m^2)	1.93 ± 0.17	
Hydration Indices		
Pre-exercise urine specific gravity	1.006 ± 0.005	1.007 ± 0.006
Body mass pre-exercise (kg)	74.59 ± 10.19	74.55 ± 10.01
Body mass postexercise (kg)	73.66 ± 10.23	73.60 ± 10.02
Sweat rate ($L \cdot h^{-1}$)	1.00 ± 0.19	1.01 ± 0.18
Post-testing hypohydration (%)	1.29 ± 0.36	1.28 ± 0.30

Data are means ± SD, N = 12.

METHODS

A randomized (order of testing), crossover, counterbalanced, repeated measures design guided data collection in this study. The independent variables were water temperature (Ten or Fifteen) and time (factor levels varied according to the dependent variable). We chose Ten and Fifteen for our water temperatures to emulate a situation where a clinician lacked access to large quantities of ice and had to use cold water rather than ice water in the body bag. Ten and Fifteen met this criteria while also still falling within professional recommendations for water temperature for EHS victims.[2]

The dependent variables were T_{REC} cooling rates and T_{REC} nadir. T_{REC} was measured every 5 min during exercise, every 0.5 min during cooling, and every 5 min during recovery. We also measured environmental chamber temperature and relative humidity, pre-exercise hydration status, and exercise duration for consistency between testing days.

Subjects

Sample size was estimated a priori using the following assumptions: an alpha value of 0.05, a difference in cooling rate of 0.10°C/min, 80% power, and a standard deviation of 0.06°C/min. Based on these assumptions, we needed 10 subjects to observe statistically significant differences in cooling rates.

We tested a convenience sample of 13 healthy, physically active, college-age men and women. One subject discontinued testing due to the difficulty of the exercise protocol. A total of 12 subjects completed testing (subject demographics can be found in **Table I**). Individuals were excluded from participating if they self-reported: 1) an injury or illness which impaired their ability to exercise; 2) any neurological, respiratory, gastrointestinal, esophageal, or cardiovascular diseases; 3) taking any medications that may have affected fluid balance or temperature regulation; 4) a sedentary lifestyle (defined as exercising <30 min three times per week)[24]; 5) a history of heat-related illness in the 6 mo preceding data collection; 6) current pregnancy; 7) cold allergy; or 8) positive COVID test result within 14 d of testing days. All women were tested within the follicular phase of their menstrual cycle (i.e., first 14 d after the onset of menstruation) and none of the women reported taking a hormone-based birth control. All subjects signed a written informed consent prior to testing and all procedures were approved by Central Michigan University Institutional Review Board.

Procedures

Procedures for this study were similar to our prior study.[13] Subjects reported for 2 d of testing between 08:00 and 17:00. Subjects were instructed to abstain from exercise (24 h) and stimulants (e.g., caffeine) and depressants (e.g., alcohol) for at least 12 h. They were instructed to drink water regularly throughout the day preceding testing to ensure their urine was clear or light yellow. Compliance with these instructions was self-reported prior to testing.

Approximately 45 min prior to the subjects' arrival, we began filling six 37.8-L (10-gal) water coolers. Due to the specificity of each water temperature in this study, we mixed ice and tap water as necessary until the water in the middle of the cooler was ~9.8°C or ~14.8°C since we anticipated the water would warm slightly while the participant exercised. No ice was visible in the coolers on each day once preparation was completed. Each cooler lid was numbered so we could average the temperatures of the water from the coolers used during treatment in the event we did not use the water from all six coolers for a participant.

Upon participants' arrival, they voided their bladders completely and a spot urine-specific gravity assessed hydration status (SUR-Ne refractometer, Atago USA Inc., Bellevue, WA, United States). If urine specific gravity indicated subjects were hypohydrated (i.e., >1.020),[21] subjects consumed ~1 L of water and urine specific gravity was reassessed ~45 min later. If subjects were still hypohydrated, they were rescheduled. If euhydrated, subjects were weighed nude (Defender #5000, Ohaus Corp, Parsippany, NJ, United States). Then they dressed in undergarments (sports bras also for women), shorts, socks, and t-shirts. We measured skinfolds at the chest, abdomen, and thigh (men) and the triceps brachii, abdomen, and thigh (women) in triplicate per Pollack, Schmidt, and Jackson[19] (baseline skinfold caliper #12-1110, Fabricated Enterprises, Inc, White Plains, NY, United States). Skinfolds were averaged at each site and summed to estimate body density[8] and percent body fat.[22] Body surface area was estimated using Dubois and Dubois's equation.[4]

Subjects donned a heart rate monitor (Polar Electro, Inc, Lake Success, NY, United States) and self-inserted a rectal thermistor (#401, Advanced Industrial Systems; Prospect, KY, United States) 15 cm past the anal sphincter.[15] They entered an environmental chamber and we recorded the environmental temperature and humidity (Kestrel Heat Stress Tracker #4400, Nielsen-Kellerman, Boothwyn, PA, United States). T_{REC} was recorded and they stood on a treadmill for 10 min to acclimate to the heat. Subjects performed an exercise protocol on a treadmill consisting of walking for 3 min at 3 mph and running at approximately 90% of their age-predicted maximum heart rate for 2 min (0% incline). When subjects' T_{REC} reached ∼38.2°C, an assistant stirred the water in each cooler and measured the water temperatures by placing a #401 thermistor approximately halfway (30.5 cm; 12 in) in the center of the cooler. Then, we moved the coolers from our main laboratory (∼22°C) inside the environmental chamber.

Once subjects' T_{REC} reached 39.5°C, they removed their shoes and lay supine inside the body bag (Polar Life Pod®, Polar Products, Inc.; **Fig. 1**). We purposefully used water temperatures at the higher end of the manufacturers[6] and expert recommendations[2] and we did not follow the manufacturer recommendation[6] to add ice or colder water to the body bag if water temperature exceeded 15°C over the course of treatment to test our hypothesis. For shorter subjects, we folded the end of the body bag closest to the subjects' feet to minimize water accumulation at the end of the unit. One investigator poured the prepared water into the body bag so subjects' torso, arms, legs, and neck were covered. Subjects' heads rested on a pillow included with the unit to ensure airway patency during cooling. A separate #401 thermistor was placed next to the subjects' neck into the water so we could monitor the water temperature in the body bag during cooling. The body bag's zipper was closed and the straps were secured. We recorded the volume of water initially added. The body bag was shaken continuously side-to-side during cooling. The body bag water temperature was also monitored and recorded once subjects' T_{REC} reached 38°C.

Fig. 1. A subject being cooled in the Polar Life Pod®.

T_{REC} was recorded every 0.5 min during cooling. A standard stopwatch was started when we began pouring water on top of subjects. The stopwatch was stopped when subjects' T_{REC} reached 38°C. Cooling rates were calculated by taking the difference in body temperatures from the end of exercise to the end of treatment and dividing it by the amount of time necessary to reduce T_{REC} to 38°C.

Subjects self-reported shivering onset during cooling so we could ascertain if shivering-induced thermogenesis affected cooling duration. Once T_{REC} was 38°C, subjects exited the body bag and towel dried their arms and legs. They sat in the environmental chamber for 10 min to recover and we recorded environmental conditions. After recovery, subjects exited the chamber, removed the rectal thermistor, towel dried, were weighed nude a second time, and excused.

No fluids were given to subjects once they entered the environmental chamber. Subjects completed their second testing day at approximately the same time of day (± 3 h) and at least 48 h after the first testing day.

Statistical Analysis

Since exercise and CWI durations differed between subjects, we only statistically compared T_{REC} at times common to all subjects. Means and standard deviations were calculated for each dependent variable and assessed for normality. Separate dependent *t*-tests were used to examine T_{REC} cooling rates, T_{REC} nadir, pre-exercise urine specific gravity, environmental conditions, and exercise durations.

We used repeated measures ANOVA to analyze T_{REC} during exercise, cooling, and recovery between conditions. Sphericity was assessed with Mauchly's test. Geisser-Greenhouse adjustments to *P*-values and degrees of freedom were made if the sphericity condition was violated. Upon significant interactions or main level effects, Tukey-Kramer post hoc tests identified differences between cooling methods at each time point. Significance was accepted when $P < 0.05$ (Number Cruncher Statistical Software v.2007, Kaysville, UT, United States).

RESULTS

All subjects self-reported compliance with testing instructions each day. Subjects were euhydrated before exercise [$t_{(11)} = 0.63$, $P = 0.54$, Table I] and exercised for similar durations [$t_{(11)} = 0.16$, $P = 0.44$, **Table II**]. Environmental chamber temperature [$t_{(11)} = 0.76$, $P = 0.46$] and humidity [$t_{(11)} = 1.1$, $P = 0.30$] were similar between days (Table II).

Table II. Exercise and Cooling Data.

EXERCISE/COOLING	TEN	FIFTEEN
Exercise Conditions		
Exercise duration (min)	46.3 ± 8.6	46.2 ± 7.8
Environment temperature (°C)	36.8 ± 0.2	36.7 ± 0.3
Environment relative humidity (%)	44 ± 1	44 ± 1
Cooling Descriptives		
T_{REC} cooling rate (°C/min) [*]	0.18 ± 0.07	0.14 ± 0.09
Nadir T_{REC} (°C)[*]	37.1 ± 0.3	37.3 ± 0.2
Preimmersion water temperature (°C)[†, ††]	10.03 ± 0.07	14.92 ± 0.04
Postimmersion water temperature (°C)[‡, ††]	13.75 ± 0.95	18.33 ± 0.97
Water volume utilized for cooling (L)[**, ††]	211.4 ± 19.5	211.4 ± 19.5
Subjects who self-reported shivering during or after CWI (*N*)[††]	11	7
Time to shivering onset (min)[††]	6.3 ± 2.7	9.3 ± 4.5

All data are means ± SD ($N = 12$). T_{REC} = rectal temperature. [*] = Significantly different between conditions ($P < 0.05$). [†] = This is the average water temperature in the coolers when T_{REC} was approximately 38.2°C during exercise. [‡] = This is the temperature of the water located near the subject's neck when T_{REC} was 38°C. [**] = These are approximate starting volumes of water used within each condition. Because the body bag was not watertight, some water was lost while attempting to fill it during cooling. [††] = Data reported descriptively and not statistically analyzed.

Subjects' T_{REC} were consistent during exercise each day and everyone discontinued exercise when T_{REC} was 39.5°C (**Fig. 2**, $P > 0.05$). However, T_{REC} cooling rates [$t_{(11)} = 2.0$, $P = 0.03$, Table II] and T_{REC} nadir differed between water temperatures [$t_{(11)} = 2.6$, $P = 0.01$, Fig. 2, Table II].

DISCUSSION

This is the second study we completed examining the effectiveness of body bag cooling as a tool for treating hyperthermia. In our first study,[13] we observed using 202.7 ± 23.8 L of 3.2°C ice water in a body bag quickly cooled subjects (0.28 ± 0.09°C/min). However, our original study presumed clinicians had access to modest quantities of ice (24 gal, 91 L) to achieve ice-water temperatures. In the current study, we intentionally filled the body bag with water at temperatures at the higher end of the manufacturer[6] and professional recommendations[2] to determine if body bag cooling would meet expert[12] recommendations for ideal or acceptable cooling. Our main observation was body bag cooling was still able to meet expert recommendations for ideal cooling with Ten and acceptable cooling with Fifteen.[12] Clinically, this means clinicians who do not have access to large quantities of ice or only have access to cold tap water can still use body bag cooling effectively so long as the water temperatures fall within official recommendations.[2] These results are encouraging because they indicate body bags can be an effective tool for treating hyperthermia, and possibly EHS, even when optimal parameters for its use are not present.

The body bag cooling rates in the current study were comparable to or exceeded the average cooling rates of several other studies examining portable CWI techniques. When authors used 2.1°C and 9°C water with TACO, they observed cooling rates of 0.14°C/min and 0.17°C/min.[7,11] More recently, Klous et al.[10] used 80 L (21 gal) of 27.2°C water and TACO and noted acceptable cooling of 0.12 ± 0.03°C/min. When unknown volumes of ice and water were put in a medical body bag up to a patient's midaxillary line, emergency room physicians observed an oral temperature cooling rate of 0.16°C/min.[9]

We acknowledge our current and prior[13] body bag results are significantly faster than Nye et al.,[18] who observed body bag cooling rates of 0.04 ± 0.08°C/min. The slow cooling rates in their study[18] were likely due to subjects being only mildly hyperthermic (T_{REC} averaged 38.4°C), the potential lack of convective cooling during treatment, and water likely accumulating at the end of the unit due to a failure to adjust the size of the body bag based on subjects' height. Regardless, the current data and those from others[7,9,11] suggest clinicians have several effective portable CWI tools available to treat EHS. Therefore, clinicians should consider athlete size, number of people available to help treat EHS victims, tool cost, and terrain when designing heat illness policy and procedure documents if these portable CWI tools are going to be used to treat EHS.

We believe the differences in cooling rates between portable CWI studies can be explained primarily by experimental differences in water volume and water temperature. Water temperature is one of the primary factors affecting cooling rates of

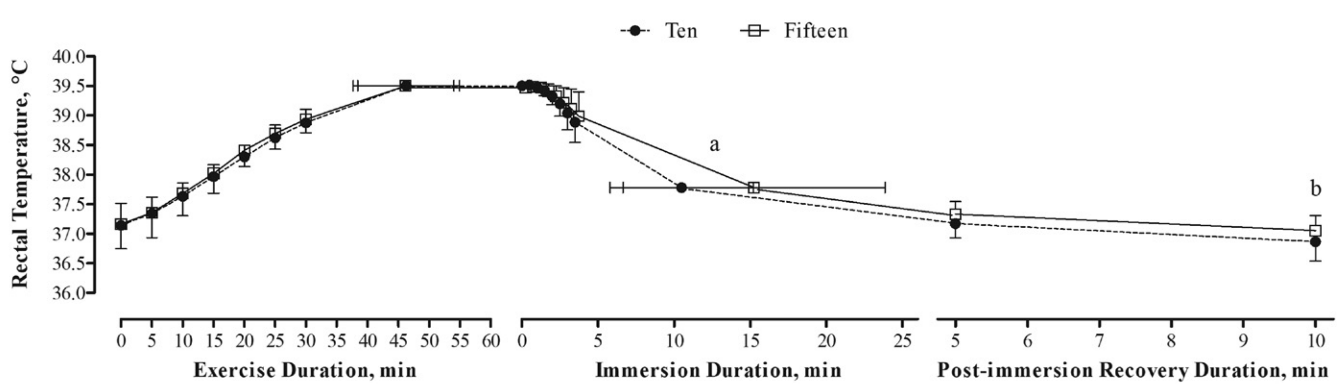

Fig. 2. Body bag cooling with two different water temperatures. Time 0 indicates the start of exercise or cooling. X-axis error bars in exercise duration and immersion duration indicate the SD of the final exercise and CWI durations. [a] = Ten cooling duration < Fifteen cooling duration [$t_{(11)} = 2.7$, $P = 0.01$]. [b] = Ten T_{REC} nadir < Fifteen T_{REC} nadir [$t_{(11)} = 2.6$, $P = 0.01$].

hyperthermic individuals and EHS patients.[20,25] Proulx et al.[20] observed some of the fastest T_{REC} cooling rates reported in the literature when hyperthermic subjects (T_{REC} = 40°C) were immersed up to their clavicles in 2°C water (0.35 ± 0.14°C/min). When warmer water temperatures of 8°C, 14°C, and 20°C were used, cooling rates slowed by 46% (0.19 ± 0.07°C/min), 57% (0.15 ± 0.06°C/min), and 46% (0.19 ± 0.10°C/min), respectively. Similarly, Miller et al.[17] observed an average cooling rate of 0.12 ± 0.05°C/min when subjects were immersed up to the neck in 21°C water. Taylor et al.[23] also observed temperate water (26°C) was capable of cooling subjects within acceptable ranges (0.10 ± 0.02°C/min). In the current study, because we did not replace or add new, colder water or ice during cooling, we observed substantial increases in water temperature within the body bag of 3.72°C (Ten) and 3.42°C (Fifteen) by the time subjects finished cooling. Even with these temperature increases, the body bag was still capable of holding enough cold water to cool at acceptable rates.

Water volume and, in turn, body surface area covered during cooling are two other important factors affecting cooling rates.[1] One advantage of body bags is water can cover the chest and most of the body (minus the face) because they can be closed around the patient. This is advantageous since it ensures greater body surface area coverage. In two of the TACO studies, authors used 30–40 gal (113 L to 151 L) of water to treat hyperthermic subjects. The smaller water volumes and fact that water often accumulates over the torso rather than fully covering the entire body with TACO is one consideration clinicians need to factor in when considering which portable tool to use. Conversely, body bags are able to accommodate about 40% more water while covering the entire body. One concern, however, is water can leak from the bag during treatment, especially from the area around the head. Regardless, having more water is desirable because, as hyperthermic subjects cool, the water inside the body bag will warm and the thermal gradient between the body and water will be reduced, leading to slower cooling rates. This explains the ∼3.5°C increase in water temperatures at the end of cooling in the body bag. We intentionally did not add any new, colder water or ice to the body bag once we began immersion to test the efficacy of the body bag with several constraints. However, if clinicians followed the manufacturer recommendation[6] to add ice or colder water if the water in the body bag exceeded 15°C, it is likely the thermal gradient would be maintained or enhanced and the cooling rates could exceed those reported in this study.

A secondary aim in this study was to determine if T_{REC} nadir could be improved with warmer water to reduce the risk of overcooling and hypothermia. While T_{REC} nadir in Ten and Fifteen were statistically different in this study, the minor difference of 0.2°C is unlikely to be clinically meaningful. However, T_{REC} nadir was ∼0.5°C higher than our first body bag study, which used ice water (∼3°C). Moreover, shivering onset was delayed 3–6 min by using Ten and Fifteen compared to our first study.[13] Consequently, using warmer water in the body bag allowed for less afterdrop and was tolerated much more effectively than ice water. Thus, it is likely fewer rewarming efforts or cold-water shock responses would occur if clinicians use Ten or Fifteen in a body bag.

We acknowledge our study's limitations. First, our subjects likely had normal thermoregulatory capabilities because none of our subjects experienced EHS. This is a common limitation of hyperthermia studies done within the context of a university laboratory setting. Studying the effect of body bag cooling in patients with EHS is necessary in the future to confirm these results. Second, the volume of water poured into the body bag for each participant varied since some water leaked out of the system, mostly near the head and rectal thermometer port, during cooling. Thus, reported immersion volumes must be considered rough estimates. Third, subjects were not immediately immersed in the body bag each day. We estimate it took ∼2 min to pour the water onto subjects, close the zipper, and secure the straps of the body bag device. Finally, we only measured T_{REC} for 10 min post-immersion. It is possible T_{REC} nadir would have been lower had the recovery period been longer. However, the cooling rates from 5 min to 10 min post-immersion in both conditions were <0.03°C/min. Consequently, we do not feel this limitation changes our clinical interpretation of the data.

In conclusion, using Ten or Fifteen in the body bag produced acceptable to ideal T_{REC} cooling rates[12] and reduced T_{REC} afterdrop. Consequently, clinicians with limited access to ice or ice-cold water can still use body bags to treat hyperthermia. However, the fastest cooling rates will occur by following professional recommendations[2] and using the coldest water. Overall, body bags may be another effective tool, like TACO,[7,10,11] for clinicians to consider when developing their heat illness policy and procedures. Future research on the effectiveness of body bags in treating EHS is still required, but these results and those of others[9,13] show promise that body bag cooling could be another life-saving technique to combat EHS mortality.

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REFERENCES

1. Belval LN, Casa DJ, Adams WM, Chiampas GT, Holschen JC, et al. Consensus statement—prehospital care of exertional heat stroke. Prehosp Emerg Care. 2018; 22(3):392–397.
2. Casa DJ, DeMartini JK, Bergeron MF, Csillan D, Eichner ER, et al. National Athletic Trainers' Association position statement: exertional heat illnesses. J Athl Train. 2015; 50(9):986–1000.
3. DeMartini JK, Casa DJ, Stearns R, Belval L, Crago A, et al. Effectiveness of cold water immersion in the treatment of exertional heat stroke at the Falmouth Road Race. Med Sci Sports Exerc. 2015; 47(2):240–245.

4. DuBois D, DuBois EF. A formula to estimate the approximate surface area if height and weight be known. Arch Intern Med (Chic). 1916; XVII(6_2): 863–871.
5. Filep EM, Murata Y, Endres BD, Kim G, Stearns RL, et al. Exertional heat stroke, modality cooling rate, and survival outcomes: a systematic review. Medicina (Kaunas). 2020; 56(11):589.
6. Polar Products. Polar Life Pod: patented cold water immersion system. [Accessed August 15, 2022]. Available from www.polarlifepod.com.
7. Hosokawa Y, Adams WM, Belval LN, Vandermark LW, Casa DJ. Tarp-assisted cooling as a method of whole-body cooling in hyperthermic individuals. Ann Emerg Med. 2017; 69(3):347–352.
8. Jackson AS, Pollock ML. Generalized equations for predicting body density of men. Br J Nutr. 1978; 40(3):497–504.
9. Kim DA, Lindquist BD, Shen SH, Wagner AM, Lipman GS. A body bag can save your life: a novel method of cold water immersion for heat stroke treatment. J Am Coll Emerg Physicians Open. 2020; 1(1):49–52.
10. Klous L, van Dieman F, Ruijs S, Gerrett N, Daanen H, et al. Efficiency of three cooling methods for hyperthermic military personnel linked to water availability. Appl Ergon. 2022; 102:103700.
11. Luhring KE, Butts CL, Smith CR, Bonacci JA, Ylanan RC, et al. Cooling effectiveness of a modified cold-water immersion method after exercise-induced hyperthermia. J Athl Train. 2016; 51(11):946–951.
12. McDermott BP, Casa DJ, Ganio MS, Lopez RM, Yeargin SW, et al. Acute whole-body cooling for exercise-induced hyperthermia: a systematic review. J Athl Train. 2009; 44(1):84–93.
13. Miller KC, Amaria NY. Excellent rectal temperature cooling rates in the Polar Life Pod consistent with stationary tubs. J Athl Train. 2023; 58(3): 244–251.
14. Miller KC, Casa DJ, Adams WM, Hosokawa Y, Cates J, et al. Roundtable on preseason heat safety in secondary school athletics: prehospital care of patients with exertional heatstroke. J Athl Train. 2021; 56(4):372–382.
15. Miller KC, Hughes LE, Long BC, Adams WM, Casa DJ. Validity of core temperature measurements at three rectal depths during rest, exercise, cold-water immersion, and recovery. J Athl Train. 2017; 52(4):332–338.
16. Miller KC, Long BC, Edwards JE. Necessity of removing American football uniforms from hyperthermic humans before cold-water immersion. J Athl Train. 2015; 50(12):1240–1246.
17. Miller KC, Truxton TT, Long BC. Temperate water immersion as a treatment for hyperthermic humans wearing American football uniforms. J Athl Train. 2017; 52(8):747–752.
18. Nye EA, Eberman LE, Games KE, Carriker C. Comparison of whole-body cooling techniques for athletes and military personnel. Int J Exerc Sci. 2017; 10(2):294–300.
19. Pollack ML, Schmidt DH, Jackson AS. Measurement of cardio-respiratory fitness and body composition in the clinical setting. Compr Ther. 1980; 6(9):12–27.
20. Proulx CI, Ducharme MB, Kenny GP. Effect of water temperature on cooling efficiency during hyperthermia in humans. J Appl Physiol. 2003; 94(4):1317–1323.
21. American College of Sports Medicine; Sawka MN, Burke LM, Eichner ER, Maughan RJ, Montain SJ, Stachenfeld NS. American College of Sports Medicine position stand. Exercise and fluid replacement. Med Sci Sports Exerc. 2007; 39(2):377–390.
22. Siri WE. Body composition from fluid spaces and density: analysis of methods. In: Brozek J, Henschel A, editors. Techniques for measuring body composition. Washington (DC): National Academies Press; 1961: 223–244.
23. Taylor NA, Caldwell JN, Van den Heuvel AM, Patterson MJ. To cool, but not too cool: that is the question–immersion cooling for hyperthermia. Med Sci Sports Exerc. 2008; 40(11):1962–1969.
24. Thompson WR, Gordon NF, Pescatello LS. Preparticipation health screening and risk stratification. In: American College of Sports Medicine. ACSM's guidelines for exercise testing and prescription. 8th ed. Baltimore: Lippincott Williams and Wilkins; 2009:18–39.
25. Zhang Y, Davis JK, Casa DJ, Bishop PA. Optimizing cold water immersion for exercise-induced hyperthermia: a meta-analysis. Med Sci Sports Exerc. 2015; 47(11):2464–2472.