Journal of Athletic Training 2023;58(3):244–251
doi: 10.4085/1062-6050-0732.21

www.natajournals.org

Excellent Rectal Temperature Cooling Rates in the Polar Life Pod Consistent With Stationary Tubs

Kevin C. Miller, PhD, ATC*; Noshir Yazdi Amaria, DO, ATC†

*Department of Health and Human Performance, Texas State University, San Marcos; †University Health Service, University of Michigan, Ann Arbor

Context: Several tools exist to reduce rectal temperature (T_{REC}) quickly for patients experiencing exertional heatstroke (EHS). Stationary tubs effectively treat EHS but are bulky and impractical in some situations. More portable cold-water immersion techniques, such as tarp-assisted cooling with oscillation, are gaining popularity because of their benefits (eg, less water needed, portability). The Polar Life Pod (PLP) may be another portable way to reduce T_{REC}, but few researchers have examined its effectiveness.

Objectives: To determine whether the PLP and stationary tub reduced T_{REC} at acceptable or ideal rates, whether T_{REC} cooling rates differed by method, and how participants felt before, during, and after cooling.

Design: Randomized crossover study.

Setting: Laboratory.

Patients or Other Participants: Thirteen individuals (8 men, 5 women; age = 21 ± 2 years, mass = 73.99 ± 11.24 kg, height = 176.2 ± 11.1 cm).

Intervention(s): Participants exercised in the heat until T_{REC} was 39.5°C. They immersed themselves in either the PLP (202.7 ± 23.8 L, 3.2 ± 0.6°C) or a stationary tub (567.8 ± 7.6 L, 15.0 ± 0.1°C) until T_{REC} was 38°C. Thermal sensation and environmental symptom questionnaire (ESQ) responses were recorded before, during, and after exercise and cooling.

Main Outcome Measure(s): Rectal temperature cooling rates, thermal sensation, and ESQ responses.

Results: Participants had similar exercise durations (PLP = 41.6 ± 6.9 minutes, tub = 42.2 ± 9.3 minutes, $t_{12} = 0.5$, $P = .31$), thermal sensation scores (PLP = 7.0 ± 0.5, tub = 7.0 ± 0.5, $P > .05$), and ESQ scores (PLP = 25 ± 13, tub = 29 ± 14, $P > .05$) immediately postexercise each day. Although T_{REC} cooling rates were excellent in both conditions, the PLP cooled faster than the stationary tub (PLP = 0.28 ± 0.09°C/min, tub = 0.20 ± 0.09°C/min, $t_{12} = 2.5$, $P = .01$). Thermal sensation in the PLP condition was lower than that in the tub condition halfway through cooling (PLP = 1 ± 1, tub = 2 ± 1, $P < .05$) and postcooling (PLP = 2 ± 1, tub = 3 ± 1, $P < .05$). The ESQ scores were higher for PLP than for the stationary tub postcooling (PLP = 25 ± 14, tub = 12 ± 9, $P < .05$).

Conclusions: The PLP and the stationary tub cooled individuals with hyperthermia at ideal rates for treating patients with EHS (ie, >0.16°C/min). The PLP may be an effective tool for treating EHS when limited water volumes and portability are concerns. Clinicians should have rewarming tools and strategies (eg, heating blankets) available to improve patients' comfort after PLP use.

Key Words: exertional heatstroke, emergency management, body bag, portability, thermal sensation

Key Points

- Both the Polar Life Pod and stationary tub cooled participants with hyperthermia at ideal rates for patients with exertional heatstroke.
- The Polar Life Pod cooled effectively with less water and ice than the stationary tub.
- Rewarming strategies should be available to enhance patient comfort after cold-water immersion.

Exertional heatstroke (EHS) is a medical emergency and 1 of the 3 leading causes of death in athletes.[1] For example, EHS continues to be a leading cause of death in American football[2] and marathon events: the EHS incidence was 3.7/10 000 starters.[3] Life-threatening heat illness is also a concern for men and women in the military and certain occupations (eg, firefighters, glass workers). The greatest risk for developing severe hyperthermia and EHS occurs when wet-bulb globe temperature is high or extreme.[4]

The current standard of care for patients with EHS includes quick recognition of severe hyperthermia via rectal temperature (T_{REC}), followed by whole-body cold-water immersion (CWI). Experts[1,5] recommend immersing EHS patients in water between 1.7°C and 15°C (35°F–59°F) within the first 30 minutes after collapse to reduce morbidity and mortality. "Acceptable" T_{REC} cooling rates for those with EHS are 0.08°C/min to 0.15°C/min, whereas "ideal" cooling rates exceed 0.16°C/min.[6] When this standard of care is followed, survival rates are 100% with minimal injury sequelae.[7]

Patients' perceptions of how hot they feel and whether they have any symptoms of exertional heat illness are also important. Thermal sensation[8,9] is a useful measure for determining the intensity of temperatures experienced by individuals. Similarly, the 16-item environmental symptom questionnaire (ESQ)[10–12] provides useful information about the severity and presence of heat-related signs or symptoms (eg, lightheadedness, feverishness). Authors have used these scales to identify whether individuals experience higher or lower degrees of thermal stress[10,13] and the usefulness of various treatments.[14,15] Experimentally, these perceptual scales provide useful information about the intensity of the exercise protocol and whether participants experienced significant thermal stress.[9,10,13] This is key because EHS cannot ethically be induced in laboratory settings. Although patient comfort should never trump safety, how patients feel after treatment may provide the clinician with meaningful recovery information when compared with pretreatment scores. For example, these tools provide useful information about the tolerability and intensity of therapeutic interventions and may help identify any clinical signs or symptoms or physiological states that indicate follow-up care (eg, rewarming) is necessary.[16]

Several tools exist for performing CWI in the field (eg, tubs, tarps). Stationary tubs (referred to hereafter as *tub* or *tubs*) are highly effective for lowering T_{REC} quickly[5,7] but may not be ideal in some clinical situations (eg, wilderness marathons). Unlike tubs, more portable CWI methods such as tarps, body bags, and the Polar Life Pod (PLP; Polar Products Inc) offer several advantages. First, these methods do not require as much water (151.4–227.1L, approximately 40–60 gal) to treat an athlete with EHS. Second, they are lightweight and portable. This reduces the need to transport an athlete to a tub, thereby minimizing delays in treatment. Third, these portable tools can be placed flat on the ground before performing CWI. Thus, the clinician or athlete does not have to step into a tub, nor would clinicians need to facilitate multiperson lift-and-carry maneuvers to perform CWI. This helps minimize the potential for secondary injury (eg, lower back injury, drops) to clinicians and athletes. Moreover, fewer trained medical personnel are needed to treat athletes who may be quite large and heavy in relation to the medical personnel.

To date, few data exist on the T_{REC} cooling rates or perceptual responses of hyperthermic humans treated with the PLP.[17] Nye et al[17] concluded that the PLP, a device similar to a body bag, was ineffective for treating severe hyperthermia. However, questions exist about whether they followed manufacturer recommendations[18] and possible flaws in the study's experimental design. In contrast, Kim et al[19] demonstrated that a body bag successfully cooled an elderly patient with heatstroke quickly (oral temperature cooling rate = 0.16°C/min) in an emergency room setting. Given the similarities between the PLP and body bags and discrepant findings, we believed further research on the PLP was necessary.

The purpose of our study was 3-fold. First, we asked whether the PLP and tub would reduce T_{REC} at acceptable or ideal rates.[6] Second, we determined if T_{REC} cooling rates differed by immersion method. Finally, to our knowledge, no investigators have examined participant perceptions after treatment with the PLP or similar device. Thus, we examined the ESQ[10] and thermal sensations of participants before, during, and after each cooling method. We hypothesized that the PLP and tub would meet or exceed acceptable T_{REC} cooling rates (ie, >0.08°C/min) and that ESQ scores and thermal sensation scores would not differ between conditions.

METHODS

Experimental Study Design

A randomized, crossover, repeated-measures design guided data collection for this study. The independent variables were cooling method (PLP or tub) and time (factor levels varied according to the dependent variable). The dependent variables were T_{REC} cooling rates, nadir T_{REC}, ESQ responses, and thermal sensation scores. We measured T_{REC} every 5 minutes during exercise and every 0.5 minutes during cooling. Participants' ESQ responses were recorded before exercise, near the end of exercise, and immediately after cooling. Thermal sensation was measured before exercise, near the end of exercise, halfway through cooling (ie, when T_{REC} was 38.75°C), and immediately after treatment. We also measured environmental chamber temperature, relative humidity, pre-exercise hydration status, exercise duration, and water temperature in the PLP and tub to ensure consistency of testing conditions between and within participants.

Table 1. Participant Demographics and Hydration Information (n = 13)[a]

	Polar Life Pod	Stationary Tub
Demographic		
Age, y	21 ± 2	
Height, cm	176.2 ± 11.1	
Body mass index	24 ± 2	
Body fat, %	14 ± 9	
Body surface area, m^2	1.90 ± 0.20	
Hydration index		
Pre-exercise urine specific gravity	1.005 ± 0.002	1.007 ± 0.006
Body mass pre-exercise, kg	73.99 ± 11.24	73.96 ± 11.08
Body mass postexercise, kg	73.12 ± 11.12	73.03 ± 11.0
Sweat rate, L/h	1.03 ± 0.33	1.06 ± 0.34
Posttesting hypohydration, %	1.2 ± 0.4	1.3 ± 0.5

[a] All data are mean ± SD; n = 13, 8 men and 5 women.

Participants

Authors[5] using CWI with water temperatures of approximately 15°C have shown cooling rates up to 0.18°C/min, whereas the only published research[17] on the PLP demonstrated an average T_{REC} cooling rate of 0.04°C/min. Thus, we estimated sample size a priori with this potential treatment effect size, an α level of .05, 80% power, and an SD of 0.08°C/min.[5] Based on these assumptions, we needed 10 participants. To increase power and include a similar number of participants as other hyperthermia studies,[9,10,15,20] we tested a convenience sample of 17 healthy, physically active men and women. Unfortunately, 4 participants discontinued testing because of the difficulty of the exercise protocol; 13 participants completed testing (Table 1). Seven individuals used a tub on the first testing day, and 6 used the PLP on the first testing day.

Recruits were excluded from the study if they self-reported (1) an injury or illness that impaired their ability to exercise; (2) any neurologic, respiratory, gastrointestinal, esophageal, or cardiovascular disease; (3) taking any medications that may have affected fluid balance or temperature regulation; (4) a *sedentary lifestyle* (defined as exercising <30 minutes, 3 times per week)[21]; (5) a history of heat-related illness in the 6 months before data collection; (6) current pregnancy; (7) cold allergy; or (8) a positive COVID test result within 14 days of testing. All women were tested within the follicular phase of their menstrual cycle (ie, first 14 days after the onset of menstruation). All participants signed a written informed consent before testing, and all procedures were approved by Central Michigan University's Institutional Review Board.

Pilot Testing

Clinicians require ice for several purposes besides emergency use (eg, first aid, cryokinetics). We sought a balance between using ice for the PLP and respecting clinicians' other needs for ice. Therefore, before testing human participants, we conducted pilot testing to determine the water temperature inside several 37.9-L (10-gal) coolers over the course of 2 hours in a 22°C laboratory. We did this to ensure that the water in the coolers could be kept within the manufacturer recommendations[18] (ie, 1.7°C–15°C) for the entirety of each trial (approximately 2 hours). We used the cooler's rough interior volumetric indicators and experimented with various combinations of crushed ice and 18.5°C tap water. Mixing 15.1 L (4 gal) of ice with 22.7 L (6 gal) of tap water consistently produced water temperatures between 2°C and 4°C. We believed that dedicating 24 gal (91.2 L) of ice across 6 coolers, approximately half of our ice machine's capacity, allowed for a valid comparison of the PLP and tub while respecting the other needs for ice clinicians might have to effectively do their jobs.

Procedures

Procedures for this study followed those of other published laboratory studies whose authors[9,20,22] investigated the effectiveness of CWI for severe hyperthermia. Participants reported for 2 days of testing between 0800 and 1600. They were instructed to abstain from exercise for 24 hours and from stimulants (eg, caffeine) and depressants (eg, alcohol) for at least 12 hours. They were instructed to drink water regularly throughout the day before testing to ensure that their urine was clear or light yellow. Compliance with these instructions was self-reported before testing.

Participants voided their bladders completely, and we obtained a spot urine specific gravity measurement to assess hydration status (SUR-Ne refractometer; Atago USA, Inc). If the urine specific gravity indicated participants were hypohydrated (ie, >1.020),[23] they consumed approximately 1 L of water, and urine specific gravity was reassessed approximately 45 minutes later. If hypohydration persisted, they were rescheduled. If euhydrated, participants were weighed nude (scale model Defender 5000; Ohaus Corp). Then, they dressed in undergarments (including sports bras 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 et al[24] (Baseline skinfold caliper model 12-1110; Fabricated Enterprises, Inc). Skinfolds were averaged at each site and summed to estimate body density[25] and percentage of body fat.[26] Body surface area was estimated using the Du Bois and Du Bois[27] equation.

Participants donned a heart rate monitor (model T31; Polar Electro) and inserted a rectal thermistor (model 401; Advanced Industrial Systems) 15 cm past the anal sphincter.[22] They entered an environmental chamber, had their T_{REC} recorded, rated their thermal sensation on a 9-point scale (0 = *unbearably cold*, 1 = *very cold*, 2 = *cold*, 3 = *cool*, 4 = *comfortable*, 5 = *warm*, 6 = *hot*, 7 = *very hot*, 8 = *unbearably hot*),[8] and completed their first ESQ. At this time, we measured environmental temperature and humidity (model 4400 Kestrel Heat Stress Tracker; Nielsen-Kellerman Co), and participants stood on a treadmill for 10 minutes to acclimate to the heat. Then they performed an incremental exercise protocol on a treadmill consisting of walking for 3 minutes at 3 miles/hour (5 km/hour) and running at approximately 80% to 90% of their age-predicted maximum heart rate for 2 minutes (0% incline).

Upon reaching a T_{REC} of approximately 39.45°C, participants rated their thermal sensation and completed a second ESQ. Once T_{REC} was 39.5°C, they stopped the treadmill and followed 1 of 2 protocols, depending on the day of testing.

On PLP days, we followed manufacturer recommendations for use.[18] Thirty minutes before each participant's arrival, we filled six 37.9-L (10-gal) water coolers with 15.1 L (4 gal) of ice and 22.7 L (6 gal) of tap water and put the lids on the coolers. Each 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 6 coolers. The coolers were kept sealed in our main laboratory (ambient temperature approximately 22°C) until participants' T_{REC} reached approximately 38.2°C. At that time, an assistant stirred the water in each cooler and measured the water temperature by placing a No. 401 thermistor approximately halfway (30.5 cm [12 in]) into the center of the cooler. Then, we moved the coolers inside the environmental chamber. Once participants' T_{REC} reached 39.5°C, they removed their shoes and lay inside the PLP. For shorter participants, we folded the end of the PLP closer to the participant's feet to minimize water accumulation at the end of the unit. One investigator poured four to six 37.9-L (10-gal) water coolers of preprepared ice and water (3.2 ± 0.6°C [38°F]) into the PLP so the individual's torso, arms, legs, and neck were covered. The participant's head rested on the pillow included with the unit to ensure airway patency during cooling. A separate No. 401 thermistor was placed next to the participant's neck in the water so we could monitor the water temperature in the PLP during cooling. The PLP zipper was closed, and the PLP straps were secured. We recorded the volume of water and ice initially added. The PLP was shaken continuously side to side during cooling (Figure 1). The PLP water temperature was also monitored continuously to ensure that the water temperature did not exceed 15°C per manufacturer instructions. Although the manufacturer recommends removing water and replacing it with more ice if the water temperature near the participant's neck exceeds 15°C,[18] we did not find this step necessary. Thus, no additional water or ice was purposefully removed or replaced after the initial water was added to the PLP. Final water temperature was recorded once the participant's T_{REC} reached 38°C in both conditions.

For tubs, we followed the National Athletic Trainers' Association (NATA) recommendations for CWI.[1] Briefly, participants removed their shoes and immersed themselves up to the neck in a 1135.6-L capacity noncirculating water tub filled with approximately 568 L (approximately 150 gal) of water (160.7 cm [length] × 175.3 cm [width] × 63.5 cm [height]; model 4247; Rubbermaid). While the participant was exercising, we monitored tub water

Figure 1. Participant immersed in the Polar Life Pod (Polar Products Inc) while investigator oscillates water.

temperature and added ice as necessary to keep it close to 15°C (59°F). We were careful to ensure that any added ice had melted before participants entered the tub. The bath was stirred continuously with a plastic rod until participants' T_{REC} was reduced to 38°C. A separate No. 401 thermistor was secured approximately 20 cm from the bottom of the tub so we could monitor and record tub water temperature during cooling.

The T_{REC} was recorded every 0.5 minutes during cooling. A standard stopwatch was started the moment the participant's foot touched the water (tub) or when the first water cooler was poured on top of participants (PLP). The stopwatch was halted when the participant's T_{REC} reached 38°C so we could calculate T_{REC} cooling rates. Cooling rates for each condition were calculated by taking the difference in body temperatures between the end of exercise and the end of treatment and dividing it by the amount of time necessary to reduce T_{REC} to 38°C.

Participants self-reported shivering onset during cooling. Halfway through cooling ($T_{REC} = 38.75$°C), they identified thermal sensation a third time. Once T_{REC} was 38°C, participants exited the PLP or tub, towel dried their arms and legs, completed a third ESQ, and reported thermal sensation a fourth time. They sat in the environmental chamber for 10 minutes to recover, and we measured environmental conditions a second time. After recovery, participants exited the chamber, removed the rectal thermistor, towel dried, were weighed nude a second time, and were excused. No fluids were given once they entered the environmental chamber. They completed their second session at approximately the same time of day (±3 hours) and at least 48 hours after the first session.

It bears explanation why we used different water temperatures and water volumes for each cooling condition. The PLP cannot contain as much water as a tub. The manufacturer[18] advises using 151 to 227 L (40–60 gal) of water. We added 570 L (150 gal) of water to the tub because it was a common size sold at various retailers and used in clinical practice. Regarding the different water temperatures in each device, 1 of the main benefits of portable CWI techniques, such as the PLP, is that less ice is needed to achieve the lower end of the recommended water temperatures for treating patients with EHS (ie, 1.7°C).[1] Consequently, devices such as the PLP can maximize the potential thermal gradient between the patient and water with fewer resources. In contrast, a major advantage of tubs is that they can hold a much higher volume of water than the PLP. However, to achieve similarly cold temperatures in a tub, we would have needed to almost completely empty our 189.3-L (50-gal) ice machine. Because we wanted to emulate the practical conditions under which clinicians use ice in their clinical practice, we elected to use similar amounts of ice (roughly 16–24 gal) for each device in our study. Consequently, this meant warmer water temperatures on tub days. Nevertheless, the tub water temperature was still within the NATA recommendation[1] for treating patients with EHS.

Statistical Analysis

Because exercise and CWI durations differed among participants, we statistically compared T_{REC} only at times common to all. Means and SDs were calculated for each dependent variable and assessed for normality. Separate dependent *t* tests were conducted to examine differences in T_{REC} cooling rates, environmental conditions, pre-exercise urine specific gravity, and exercise durations because the data were normally distributed. Wilcoxon signed rank tests were computed when normality was violated, with the median and interquartile range reported (eg, nadir T_{REC}).

For ESQ responses, we summed the scores from the 16 items and created a new cumulative score.[10] The cumulative scores were analyzed with a repeated-measures analysis of variance (ANOVA). Although thermal sensation is technically categorized as ordinal data, we elected to use a repeated-measures ANOVA to analyze this variable for 2 reasons. First, thermal sensation data are prone to large numbers of ties, and nonparametric models that use ranking to analyze for differences are not robust enough to overcome data with a large number of ties. Second, prior investigators[8,9,13,14] used parametric statistics to analyze thermal sensation data.

A separate repeated-measures ANOVA also examined differences in T_{REC} during exercise, cooling, and recovery between conditions. We assessed sphericity with the Mauchly 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 $P < .05$ (version 2007; Number Cruncher Statistical Software; NCSS, LLC).

RESULTS

All participants self-reported compliance with testing instructions each day. They were well hydrated before exercise ($t_{12} = 1.4$, $P = .10$; Table 1) and exercised for similar durations each day ($t_{12} = 0.5$, $P = .31$; Table 2). The environmental chamber temperature was slightly warmer on PLP days ($t_{12} = 5.0$, $P < .001$), but relative humidity was slightly higher on tub days ($t_{12} = 2.7$, $P = .01$; Table 2).

The T_{REC} was comparable between conditions during exercise, and all participants discontinued exercise when T_{REC} was 39.5°C. Although T_{REC} was comparable between conditions in the first minutes of cooling, individuals were

Table 2. Exercise and Cooling Data (n = 13)[a]

Variable	PLP	Stationary Tub
Exercise condition		
Exercise duration, min	41.6 ± 6.9	42.2 ± 9.3
Environment temperature, °C[b]	38.6 ± 0.2	38.1 ± 0.2
Environment relative humidity, %[b]	45 ± 1	47 ± 1
Cooling variable		
Preimmersion water temperature, °C[c,d]	3.2 ± 0.6	15.0 ± 0.1
Postimmersion water temperature, °C[d,e]	4.5 ± 2.3	15.7 ± 0.2
Water volume used for cooling, L[d,f]	202.7 ± 23.8	567.8 ± 7.6
T_{REC} cooling rate, °C/min[b]	0.28 ± 0.09	0.20 ± 0.09
Nadir T_{REC}, °C[b]	36.6 (0.9)	37.5 (1.2)
Participants who self-reported shivering during or after cold-water immersion, No.[d]	10	8
Time to shivering onset, min[d]	3.8 ± 1.8	6.2 ± 3.2

Abbreviations: PLP, Polar Life Pod; T_{REC}, rectal temperature.

[a] All data are mean ± SD except for nadir $T_{REC,}$ which is reported as median and interquartile range (n = 13), and participants with self-reported shivering after cold-water immersion.

[b] Indicates difference between conditions ($P < .05$).

[c] For PLP, this was the average water temperature in the coolers. For a stationary tub, this was the temperature at 20 cm from the bottom of the tub.

[d] Data were reported descriptively and not statistically analyzed.

[e] For PLP, this was the temperature of the water located near the participant's neck when T_{REC} was 38°C.

[f] These were approximate starting volumes of water used in each condition. Because the PLP was not watertight, some water was lost while we filled the PLP and during cooling.

in the PLP for shorter durations than in the tub (Figure 2). This resulted in faster T_{REC} cooling rates in the PLP than in the tub ($t_{12} = 2.5$, $P = .01$; Table 2). The T_{REC} continued to decline even during recovery and displayed a lower nadir in the PLP ($z_{12} = 3.2$, $P < .001$; Table 2).

The ESQ scores ($F_{2,24} = 15.4$, $P < .001$; Table 3) and thermal sensation ($F_{3,36} = 5.9$, $P = .002$; Figure 3) differed between conditions over time. For the PLP, thermal sensation was lower at the halfway point (ie, T_{REC} at 38.75°C) and immediately postcooling than for the tub ($P < .05$). The ESQ scores differed at pre-exercise from postexercise and postcooling in both conditions. Although ESQ scores dropped postcooling compared with postexercise in the tub, this was not observed in the PLP. In fact, the PLP ESQ scores were higher than tub ESQ scores postcooling ($P < .05$).

DISCUSSION

Our main observation was that both the PLP and tub had excellent cooling rates in men and women with hyperthermia who did not experience EHS. The PLP cooling rate actually exceeded that of tubs and other portable CWI methods reported in the literature (eg, tarp-assisted cooling with oscillation [TACO], body bags).[19,28,29] Hosokawa et al[28] used TACO to cool participants with hyperthermia ($T_{REC} = 39.73°C \pm 0.27°C$) by placing them in a tarp with 113.6 L (30 gal) of approximately 9°C water. Participants cooled at 0.17 ± 0.07°C/min. Others[29] demonstrated that 151 L (40 gal) of 2.1°C water using TACO cooled at 0.14 ± 0.06°C/min.

Our cooling rates were likely higher than those of TACO[28,29] for 2 reasons. First, we used a higher water volume and colder water. Second, the design of the PLP allows for more body surface area coverage and full-body immersion, whereas TACO often only covers the posterior half of the body. To our knowledge, the authors[19] of only 1 study have used medical body bags, similar to the PLP, to treat heatstroke. Emergency room physicians cooled an elderly woman who collapsed with classic heatstroke by placing her in a body bag filled with ice and water up to the anterior axillary line.[19] Based on her oral temperatures before and after cooling, she cooled at a rate of 0.16°C/min. However, it is unclear how much ice or water was used in

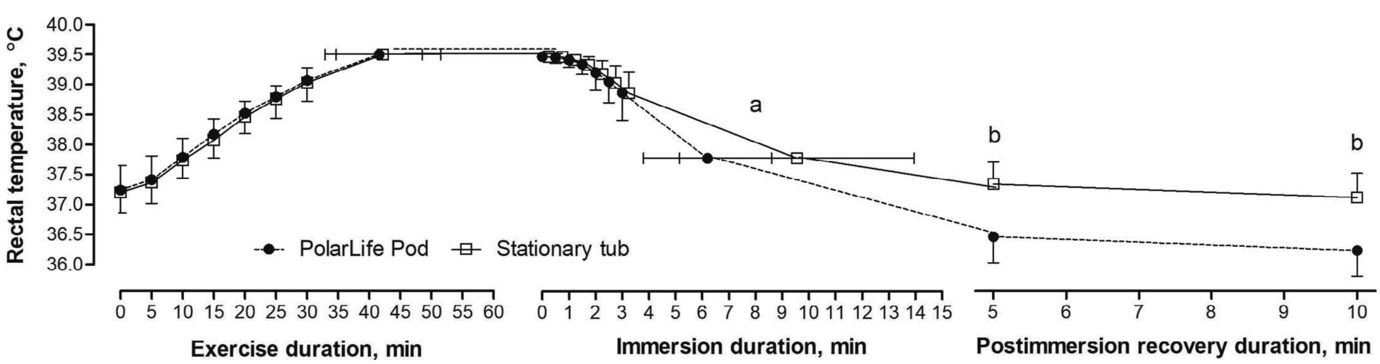

Figure 2. Time 0 indicates the start of exercise or cooling. The x-axis error bars in exercise duration and immersion duration indicate the SD of the final exercise and cold-water immersion durations. Abbreviation: PLP, Polar Life Pod; TUB, stationary tub. [a] Duration of PLP cooling < TUB cooling ($t_{12} = 2.5$, $P = .01$). [b] PLP < TUB ($P < .05$).

Table 3. Environmental Symptoms Questionnaire Responses With the Polar Life Pod (PLP) and Stationary Tub, Mean ± SD (n = 13)[a]

Variable	PLP	Stationary Tub
Pre-exercise	2 ± 2[b]	2 ± 2[b]
Postexercise	25 ± 13	29 ± 14
Postcooling	25 ± 14[c]	12 ± 9[d]

[a] The 16-item Environmental Symptoms Questionnaire is rated on a 5-point Likert scale with scores ranging from 0 (*not at all*) to 5 (*extreme*).
[b] Pre-exercise in both conditions < all other times in each condition ($P < .05$).
[c] The PLP postcooling > stationary tub postcooling ($P < .05$).
[d] Stationary tub postcooling < postexercise ($P < .05$).

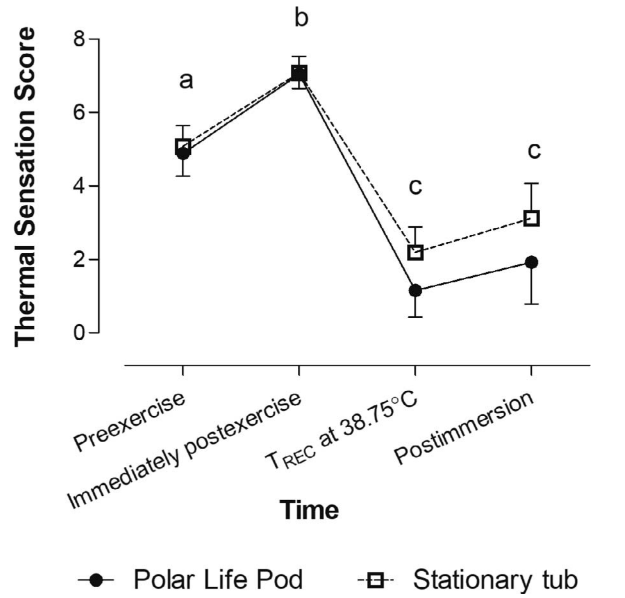

Figure 3. Thermal sensation scores between the PLP and TUB. Abbreviations: PLP, Polar Life Pod; T_{REC}, rectal temperature, TUB, stationary tub. [a] The PLP and TUB pre-exercise differed from all other times in their respective conditions. [b] The PLP and TUB postexercise > T_{REC} at 38.75°C and postimmersion. [c] PLP < TUB. All superscripts indicate significance at $P < .05$.

resuscitation efforts. Given our cooling rates, we concluded that the PLP successfully reduced the body core temperature of individuals with severe hyperthermia and shows promise as an EHS treatment tool. Similarly, clinicians can continue to be confident using tubs for EHS treatment.[5]

We propose 3 reasons why we observed much faster cooling rates than Nye et al,[17] who reported a PLP T_{REC} cooling rate of 0.04 ± 0.08°C/min. First, we strictly followed the manufacturer recommendations for use. Specifically, this included adjusting the size of the PLP based on each participant's height. Folding the end of the PLP was important to minimize the volume of water at the bottom of the unit and helped ensure that water covered as much body surface area as possible. Also, we oscillated the water inside the PLP during cooling. Shaking the PLP ensured conductive and convective cooling, thereby facilitating the cooling process. It is unclear how much water Nye et al[17] used for each participant, though they described using an unknown volume of ice and 40 to 80 gal (151–303 L) of water. It is also unclear whether they oscillated the water during treatment. Second, our participants were immersed in colder water (3.2°C ± 0.6°C) than those in the Nye et al[17] study. This is important because water temperature greatly influences cooling; Proulx et al[30] determined that cooling rates were 46% and 57% faster, respectively, when participants were immersed in 2°C than 8°C or 14°C water. Because Nye et al[17] did not record the water temperature before participants were immersed in the PLP, this could explain the larger variability in the water temperatures reported (5°C–10°C). Third, our participants began cooling once T_{REC} was 39.5°C, as opposed to 38.4 ± 0.7°C.[17] Our participants were hotter, so a larger temperature gradient existed, and our participants cooled faster.

Our study had several additional strengths. First, we standardized the water volumes and temperatures used on each testing day and recorded water temperature during cooling. Second, we monitored when participants self-reported shivering. As expected, fewer individuals shivered in a tub than in the PLP, and they experienced less time shivering during cooling. This was likely due to the differences in water temperatures between conditions and the fact that skin temperature is a primary driver in the onset of shivering.[31] Third, our participants reported their perceptions of how they felt before, during, and after treatment. Despite having similar thermal sensation and ESQ scores before and after exercise, they felt much colder and had higher ESQ scores after PLP treatment. Although the people in tubs felt better postcooling than postexercise, this did not occur in the PLP. The extremely cold water temperatures used on the PLP day (approximately 3°C versus 15°C) were likely responsible. Anecdotally, some participants described feeling pain in their hands and feet during the PLP treatment that was not reported in the tub treatment. Previously, we[15] noted that participants better tolerated and reported feeling more comfortable during and after water immersion when 21°C water was used to treat hyperthermia. However, the cooling rate with these warmer water baths was only acceptable (0.12 ± 0.05°C/min) and not ideal.[15] Therefore, although the PLP was quite effective in reducing T_{REC}, the low water temperatures induced significant shivering, higher ESQ scores, and much lower nadir T_{REC} values. Consequently, clinicians who use the PLP at water temperatures comparable with what we used should heed the NATA's recommendation[1] to remove patients from the PLP when T_{REC} is 38.9°C and be prepared with rewarming strategies to help patients feel better and prevent hypothermic afterdrop.

We acknowledge our study's limitations. First, for safety reasons, none of our participants experienced EHS. Second, we used the 10-gal (37.9-L) coolers' rough volumetric markers to estimate how much ice and water to add to each cooler. Thus, variations in water temperatures occurred on the PLP days among participants. Third, despite our recording of the volume of water poured into the PLP for each individual, some water inevitably leaked out of the system during cooling or was lost during our attempt to pour water into the unit. Hence, the immersion volumes we identified must be considered rough estimates. Fourth, participants were not immediately fully immersed on the PLP day as they were on the tub day. We estimate it took approximately 2 minutes to pour all of the necessary water on the participants, close the zipper, and secure the straps on the PLP. If clinicians have more than 1 person pouring water on the participant, the PLP cooling rate may be even higher than the rates demonstrated here.

Finally, we acknowledge that some clinicians may have financial constraints or limitations on the equipment they are able to purchase in the case of emergencies. At the time of this study, the PLP cost approximately $425. In comparison, tarps for TACO, kiddie pools, or medical body bags may be purchased for less than $100, whereas a tub can cost up to $450, depending on size. Overall, each method of CWI has its own advantages and disadvantages. For example, TACO provides acceptable to ideal cooling[28,29] but requires help from several assistants to ensure that the patient's airway remains patent during treatment and that water covers as much body surface area as possible. Thus, it is vitally important that clinicians weigh and consider these points while also considering cooling effectiveness data when developing EHS policy and procedure documents.

In summary, despite using 2.5 to 3.0 times less water and ice than a tub, the PLP cooled hyperthermic men and women at ideal cooling rates for EHS. However, the intensity of the cold water induced more perceived stress during and after cooling. Thus, if clinicians cool individuals with the PLP using similar water temperatures, they should remove patients from the device at T_{REC} consistent with NATA recommendations[1] and have rewarming tools (eg, heated blankets) available. Future researchers may explore the use of the PLP in patients with EHS and whether these negative side effects can be mitigated by using warmer water in PLP while still maintaining its ideal cooling rate.

ACKNOWLEDGMENTS

We thank Polar Products, Inc, for sponsoring this project and all the participants who volunteered their time and energy during data collection. We also thank Connor Shea, London Ross, and Andrea Willsey for their help with data collection.

REFERENCES

1. Casa DJ, DeMartini JK, Bergeron MF, et al. National Athletic Trainers' Association position statement: exertional heat illnesses. *J Athl Train*. 2015;50(9):986–1000. doi:10.4085/1062-6050-50.9.07
2. Kucera KL, Klossner D, Colgate B, Cantu RC. Annual survey of football injury research: 1931–2018. National Center for Catastrophic Sport Injury Research. 2019. Accessed July 2, 2019. https://nccsir.unc.edu/wp-content/uploads/sites/5614/2019/02/Annual-Football-2018-Fatalities-FINAL.pdf
3. Breslow RG, Collins JE, Troyanos C, et al. Exertional heat stroke at the Boston marathon: demographics and the environment. *Med Sci Sports Exerc*. 2021;53(9):1818–1825. doi:10.1249/MSS.0000000000002652
4. Cooper ER, Ferrara MS, Broglio SP. Exertional heat illness and environmental conditions during a single football season in the Southeast. *J Athl Train*. 2006;41(3):332–336.
5. 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. doi:10.1249/MSS.0000000000000693
6. McDermott BP, Casa DJ, Ganio MS, et al. Acute whole-body cooling for exercise-induced hyperthermia: a systematic review. *J Athl Train*. 2009;44(1):84–93. doi:10.4085/1062-6050-44.1.84
7. DeMartini JK, Casa DJ, Stearns RL, 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. doi:10.1249/MSS.0000000000000409
8. Young AJ, Sawka MN, Epstein Y, Decristofano B, Pandolf KB. Cooling different body surfaces during upper and lower body exercise. *J Appl Physiol (1985)*. 1987;63(3):1218–1223. doi:10.1152/jappl.1987.63.3.1218
9. Miller KC, Long BC, Edwards J. Necessity of removing American football uniforms from humans with hyperthermia before cold-water immersion. *J Athl Train*. 2015;50(12):1240–1246. doi:10.4085/1062-6050-51.1.05
10. Johnson EC, Ganio MS, Lee EC, et al. Perceptual responses while wearing an American football uniform in the heat. *J Athl Train*. 2010;45(2):107–116. doi:10.4085/1062-6050-45.2.107
11. Miller KC, Di Mango TD, Katt GE. Cooling rates of hyperthermic humans wearing American football uniforms when cold-water immersion is delayed. *J Athl Train*. 2018;53(12):1200–1205. doi:10.4085/1062-6050-398-17
12. Stearns RL, Belval LN, Casa DJ, et al. Two environmental symptoms questionnaires during 10 days of exercise-heat acclimation. *Aviat Space Environ Med*. 2013;84(8):797–802. doi:10.3357/asem.3154.2013
13. Taylor J, Miller KC. Precooling, hyperthermia, and postexercise cooling rates in humans wearing American football uniforms. *J Athl Train*. 2019;54(7):758–764. doi:10.4085/1062-6050-175-18
14. DeMartini JK, Ranalli GF, Casa DJ, et al. Comparison of body cooling methods on physiological and perceptual measures of mildly hyperthermic athletes. *J Strength Cond Res*. 2011;25(8):2065–2074. doi:10.1519/JSC.0b013e3182259b1d
15. Miller KC, Truxton T, Long B. Temperate-water immersion as a treatment for hyperthermic humans wearing American football uniforms. *J Athl Train*. 2017;52(8):747–752. doi:10.4085/1062-6050-52.5.05
16. Tipton MJ, Collier N, Massey H, Corbett J, Harper M. Cold water immersion: kill or cure? *Exp Physiol*. 2017;102(11):1335–1355. doi:10.1113/EP086283
17. 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.
18. Polar Life Pod: cold water immersion system. Accessed July 12, 2017. www.polarlifepod.com
19. 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. doi:10.1002/emp2.12007
20. Miller KC, Swartz EE, Long BC. Cold-water immersion for hyperthermic humans wearing football uniforms. *J Athl Train*. 2015;50(8):792–799. doi:10.4085/1062-6050-50.6.01
21. Thompson WR, Gordon NF, Pescatello LS. Preparticipation health screening and risk stratification. In: *ACSM's Guidelines for Exercise Testing and Prescription*. 8th ed. Lippincott Williams and Wilkins; 2009:18–39.
22. Miller KC, Hughes LE, Long BC, Adams WM, Casa DJ. Validity of core temperature measurements at 3 rectal depths during rest, exercise, cold-water immersion, and recovery. *J Athl Train*. 2017;52(4):332–338. doi:10.4085/1062-6050-52.2.10
23. 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. doi:10.1249/mss.0b013e31802ca597
24. 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.
25. Jackson AS, Pollock ML. Generalized equations for predicting body density of men. *Br J Nutr*. 1978;40(3):497–504. doi:10.1079/bjn19780152

26. Siri WE. Body composition from fluid spaces and density: analysis of methods. In: Brozek J, Henschel A, eds. *Techniques for Measuring Body Composition*. National Academies Press; 1961:223–244. Accessed November 16, 2021. https://apps.dtic.mil/sti/citations/AD0286506
27. Du Bois D, Du Bois EF. A formula to estimate the approximate surface area if height and weight be known: 1916. *Nutrition*. 1989;5(5):303–311; discussion 312–313.
28. 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. doi:10.1016/j.annemergmed.2016.08.428
29. Luhring KE, Butts CL, Smith CR, et al. Cooling effectiveness of a modified cold-water immersion method after exercise-induced hyperthermia. *J Athl Train*. 2016;51(11):946–951. doi:10.4085/1062-6050-51.12.07
30. Proulx CI, Ducharme MB, Kenny GP. Effect of water temperature on cooling efficiency during hyperthermia in humans. *J Appl Physiol (1985)*. 2003;94(3):1317–1323. doi:10.1152/japplphysiol.00541.2002
31. Castellani JW, Young AJ. Human physiological responses to cold exposure: acute responses and acclimatization to prolonged exposure. *Auton Neurosci*. 2016;196:63–74. doi:10.1016/j.autneu.2016.02.009

Address correspondence to Kevin C. Miller, PhD, ATC, Department of Health and Human Performance, Texas State University, San Marcos, TX 78666. Address email to kmiller@txstate.edu.