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Cold-Water Immersion for Hyperthermic Humans Wearing American Football Uniforms

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Context: Current treatment recommendations for American football players with exertional heatstroke are to remove clothing and equipment and immerse the body in cold water. It is unknown if wearing a full American football uniform during cold-water immersion (CWI) impairs rectal temperature (T_{rec}) cooling or exacerbates hypothermic afterdrop.

Objective: To determine the time to cool T_{rec} from 39.5°C to 38.0°C while participants wore a full American football uniform or control uniform during CWI and to determine the uniform's effect on T_{rec} recovery postimmersion.

Design: Crossover study.

Setting: Laboratory.

Patients or Other Participants: A total of 18 hydrated, physically active, unacclimated men (age = 22 ± 3 years, height = 178.8 ± 6.8 cm, mass = 82.3 ± 12.6 kg, body fat = 13% ± 4%, body surface area = 2.0 ± 0.2 m^2).

Intervention(s): Participants wore the control uniform (undergarments, shorts, crew socks, tennis shoes) or full uniform (control plus T-shirt; tennis shoes; jersey; game pants; padding over knees, thighs, and tailbone; helmet; and shoulder pads). They exercised (temperature approximately 40°C, relative humidity approximately 35%) until T_{rec} reached 39.5°C. They removed their T-shirts and shoes and were then immersed in water (approximately 10°C) while wearing each uniform configuration; time to cool T_{rec} to 38.0°C (in minutes) was recorded. We measured T_{rec} (°C) every 5 minutes for 30 minutes after immersion.

Main Outcome Measure(s): Time to cool from 39.5°C to 38.0°C and T_{rec}.

Results: The T_{rec} cooled to 38.0°C in 6.19 ± 2.02 minutes in full uniform and 8.49 ± 4.78 minutes in control uniform (t_{17} = –2.1, P = .03; effect size = 0.48) corresponding to cooling rates of 0.28°C·min^{-1} ± 0.12°C·min^{-1} in full uniform and 0.23°C·min^{-1} ± 0.11°C·min^{-1} in control uniform (t_{17} = 1.6, P = .07, effect size = 0.44). The T_{rec} postimmersion recovery did not differ between conditions over time ($F_{1,17}$ = 0.6, P = .59).

Conclusions: We speculate that higher skin temperatures before CWI, less shivering, and greater conductive cooling explained the faster cooling in full uniform. Cooling rates were considered ideal when the full uniform was worn during CWI, and wearing the full uniform did not cause a greater postimmersion hypothermic afterdrop. Clinicians may immerse football athletes with hyperthermia wearing a full uniform without concern for negatively affecting body-core cooling.

Key Words: heatstroke, rectal temperature, whole-body immersion

Key Points

- Body core-temperature cooling was excellent in participants wearing full American football uniforms during cold-water immersion.
- Wearing a full American football uniform after cold-water immersion did not result in excessive overcooling.
- Participants cooled faster in the full-uniform condition than in the control-uniform condition.
- Researchers should develop treatment protocols to improve outcomes and ensure the most efficient means of treating American football players with hyperthermia.

Exertional heatstroke (EHS) is a medical emergency diagnosed when body core temperature (T_{core}) is greater than 40°C and central nervous system dysfunction is displayed.[1–3] The possibility of neurologic deterioration, organ failure, and death increases with increasing duration of T_{core} greater than 40°C.[4–7] Therefore, the immediate treatment priority is to initiate cold-water immersion (CWI) and lower T_{core} as rapidly as possible.[6,8,9]

American football athletes are susceptible to EHS, in part, due to the equipment-intensive nature of the sport. Recent prevalence trends have indicated a problem: 30 American football athletes died due to EHS between 2003 and 2011 compared with 22 in the 10 years before that time.[10] Football athletes typically exercise outdoors starting in the late summer (eg, August in North America) in 1 of 3 uniform configurations: (1) a full uniform consisting of undergarments; shorts; crew socks; shoes; jersey; game pants; padding over the knees, thighs, and tailbone; helmet; and shoulder pads; (2) a partial uniform consisting of helmet, undergarments, shorts, crew socks, shoes, jersey, and shoulder peds; or (3) shorts, crew socks, shoes, and shirt.[11,12]

The National Athletic Trainers' Association,[8] American College of Sports Medicine,[13] and expert consensus[14] have recommended removing clothes and equipment before CWI if an American football athlete has EHS. These recommen-

Table 1. Participant Demographics (N = 18)

Characteristic	Mean ± SD
Age, y	22 ± 3
Height, cm	178.8 ± 6.8
Body mass index	25.7 ± 3.5
Sum of skinfolds, mm	46.6 ± 12.3
Body density, g/cc	1.07 ± 0.01
Body fat, %	13 ± 4
Body surface area, m^2	2.0 ± 0.2

Table 2. Participant Descriptive Information (Mean ± SD; N = 18)

	Condition	
Characteristic	Full American Football Uniform[a]	Control Uniform[b]
Pre-exercise urine specific gravity	1.006 ± 0.005	1.006 ± 0.005
Pre-exercise body mass, kg	82.3 ± 12.6	82.5 ± 12.9
Postrecovery body mass, kg	81.2 ± 12.5	81.3 ± 12.7
Sweat rate, $L \cdot h^{-1}$	1.6 ± 0.4	1.5 ± 0.4
Hypohydration, %	1.3 ± 0.3	1.5 ± 0.4

[a] For the full American football uniform condition, each participant wore undergarments; shorts; crew socks; tennis shoes; T-shirt; jersey; game pants; padding over the knees, thighs, and tailbone; helmet; and shoulder pads.

[b] For the control uniform condition, each participant wore undergarments, shorts, crew socks, tennis shoes, and a T-shirt that was removed before cooling.

dations appear to be based on examinations of T_{core} cooling of participants immersed in cold water while wearing little clothing[15–20] or examinations of T_{core} of participants exercising in hot conditions while wearing full American football equipment.[11,21,22] To our knowledge, no researchers have addressed whether wearing a full American football uniform during CWI impedes T_{core} cooling. This issue requires clarification because removing athletic equipment before CWI may take several minutes depending on personnel, location, and the size and temperament of the athlete.[23] Any reduction in the delay in treatment, regardless of how small, would help clinicians more efficiently treat football athletes with EHS and ensure prompt CWI.

Overcooling (ie, hypothermic afterdrop) is also a concern with CWI.[15,20,24,25] Hypothetically, wearing a full uniform after CWI could impair T_{core} rewarming in 2 ways. First, the full uniform would insulate the body,[26] thereby potentially sealing in the cold. Second, the cooled clothing and equipment would continue to reduce T_{core} via conduction. No data exist on the effect of T_{core} rewarming in players wearing a full uniform. Therefore, the primary purpose of our study was to examine the time required to reduce rectal temperatures (T_{rec}) of persons with hyperthermia cooled via CWI while wearing a full uniform or a control uniform. A secondary purpose was to determine how wearing a full uniform affects T_{rec} recovery after CWI. We hypothesized that participants wearing a full uniform would need longer to cool from 39.5°C to 38.0°C and would have lower T_{rec} postimmersion.

METHODS

Experimental Design

We used a crossover design with repeated measures to guide data collection. To determine how equipment affects T_{rec} cooling times, our independent variable was equipment condition (full, control). To determine how equipment affects T_{rec} recovery, the independent variables were equipment condition and time (0, 5, 10, 15, 20, 25, and 30 minutes after immersion). Participants selected a number from a hat on the first day of testing that corresponded to a treatment order (eg, full and then control uniform or vice versa). The order of uniform conditions was counterbalanced before testing. The dependent variables were the time needed to cool participants from 39.5°C to 38.0°C (in minutes) and T_{rec} (in degrees Celsius).

Participants

Based on the assumption that a 5-minute difference in cooling time is clinically meaningful,[23] 15 participants were needed to detect a difference at 80% power with an α level of .05. We elected to test 18 participants to ensure adequate power.

A convenience sample of 18 healthy, recreationally active, unacclimated men was recruited and completed the hyperthermia and immersion protocol. Participant demographics and descriptive information are given in Tables 1 and 2. Volunteers were excluded from participating if they self-reported (1) an injury that precluded their ability to exercise (ie, run and walk); (2) any neurologic, respiratory, or cardiovascular disease; (3) taking any medications (eg, diuretics) that may have affected fluid balance or temperature regulation; (4) a *sedentary lifestyle*, which was defined as exercising less than 30 minutes 3 times per week[27]; (5) a history of heat-related illness (eg, heat exhaustion) in the 6 months preceding data collection; or (6) illness or fever at the time of data collection. Participants provided written informed consent, and the study was approved by Central Michigan University's Institutional Review Board.

Procedures

Participants reported for 2 days of testing separated by 72 hours. Testing occurred between 8:00 AM and 5:00 PM; however, each participant underwent testing at approximately the same time of day. We instructed participants to avoid exercise, stimulants, or depressants for 48 hours before testing; maintain a normal diet; drink water consistently preceding testing; and fast for 2 hours before testing. Participants were instructed to consume the same meal the night before each testing session. Compliance with these instructions was self-reported by the participants before each testing day.

On testing days, participants voided their bladders completely, and urine specific gravity was assessed using a refractometer (SUR-Ne refractometer; Atago USA Inc, Bellevue, WA). If participants were hypohydrated (urine specific gravity $>$ 1.020),[28] they were rescheduled for another testing day at least 48 hours later. If they were euhydrated, they were weighed nude (Defender 5000; Ohaus Corp, Parsippany, NJ). Skinfold thicknesses were measured in triplicate and averaged for the chest, abdomen, and thigh per the instructions of Pollack et al[29] (Baseline medical skinfold caliper model 12-1110; Fabrication Enterprises, Inc, White Plains, NY). Skinfolds were

Table 3. Clothing and Equipment Worn During Exercise or Cooling

Equipment Condition	Clothing and Equipment Worn[a]
Control uniform	Undergarments,[b] shorts,[c] crew socks,[d] T-shirt,[e] and tennis shoes[f]
Full American football uniform	Undergarments,[b] shorts,[c] crew socks,[d] T-shirt,[e] tennis shoes,[f] jersey,[g] game pants,[h] knee pads,[i] thigh pads,[j] tailbone pad,[k] helmet,[l] and shoulder pads[m]

[a] Equipment was kept in the laboratory, laundered between trials, and dried fully before testing for each participant.
[b] Participants wore undergarments that they provided. Undergarment type and fabric composition were not controlled and likely varied among participants.
[c] Participants wore shorts that they provided. Shorts did not extend past the knee, and the length, type, and fabric composition were not controlled and likely varied among participants.
[d] Participants wore cotton crew socks that were extended to cover the soleus muscle.
[e] Participants wore T-shirts with sleeves that they provided and that extended over the deltoid muscle group. Fabric composition was not controlled and likely varied among participants. T-shirts were removed immediately before cooling on the control uniform day.
[f] During exercise, participants wore tennis shoes that they provided. Shoes were removed immediately before cooling on both testing days.
[g] Pro-practice 54 porthold mesh jersey (Adidas AG, Herzogenaurach, Germany) that extended to the waist.
[h] Classic 3-panel pant (89% polyester, 11% spandex) with fang insert (Adidas AG).
[i] Foam knee pads (model MJ-P; Adams USA Inc, Cookeville, TN) that weighed 31.5 g and were 18 cm long, 14.5 cm wide, and 1 cm deep. Knee pads were placed into the pouches in the game pants.
[j] Foam thigh pads (model TL-1350; Adams USA Inc) that weighed 48.7 g and were 18.5 cm long, 16 cm wide, and 2 cm deep. Thigh pads were placed into the pouches in the game pants.
[k] Foam tailbone pad (model AHM 1/4; Adams USA Inc) that weighed 13.7 g and were 19 cm long, 6 cm wide, and 0.5 cm deep. Tailbone pads were placed between the shorts and football pants and kept in place by the pressure exerted by the pants belt.
[l] Riddell Revolution Speed helmet with G2BD mask (Easton-Bell Sports, Van Nuys, CA) with standard padding inside the helmet.
[m] SP Mr. DZ Lineman shoulder pads (Douglas Pads & Sports, Inc, Houston, TX) in size XL.

summed and used to estimate body density[30] and body fat percentage.[31] Body surface area was estimated using the equation of Dubois and Dubois[32] (Table 1).

Participants donned a heart rate monitor (Polar Electro, Inc, Lake Success, NY) and inserted a rectal thermistor (YSI 4600 Precision Thermometer with 401 probe; Advanced Industrial Systems Inc, Prospect, KY) at least 20 cm past the anal sphincter. Next, they put on either a control or full uniform (Table 3). They wore the same shorts, crew socks, shoes, and T-shirts on both testing days. Participants entered an environmental chamber and stood on a treadmill (model 1850; Proform Performance, Logan, UT) for 10 minutes to acclimate to the environment.[11] The T_{rec} and environmental chamber conditions were recorded (Table 4). Participants walked for 3 minutes at 3 miles per hour and then ran at 90% of their age-predicted maximum heart rate for 2 minutes at a 0% incline. They repeated this walking/running protocol until their T_{rec} reached 39.5°C. We continuously monitored T_{rec} during exercise to determine when participants reached the thermal threshold. Environmental chamber conditions were also recorded immediately after exercise.

After reaching thermal threshold (ie, 39.5°C), participants stopped exercising; stepped off the treadmill; removed their shoes on the full-uniform day or shoes and T-shirts on the control-uniform day; and entered a 1135.6–L capacity, noncirculating water tub (model 4247; Newell Rubbermaid, Atlanta, GA) that was 160.7 cm long, 175.3 cm wide, and 63.5 cm high. Participants immersed themselves up to the neck for the duration of cooling; all other body parts remained under the water for the duration of cooling. Transfer time from treadmill to bath was approximately 10 seconds. A stopwatch (Acu-Rite, Schaumburg, IL) was started the moment each participant's foot touched the water.

We secured insulated thermocouples (model PT-6 Kapton; Physitemp Instruments, Inc, Clifton, NJ) at 3 depths (1.5 cm, 21 cm, and 38.0 cm) from the bottom of the water bath to ensure that the initial water-bath temperature remained at approximately 10°C (Table 4). Investigators ensured that any ice added to the bath melted before participant entry so ice did not accumulate near the thermocouples, thereby skewing the water-bath temperatures. Participants placed their hands up to their wrists in 2

Table 4. Exercise Duration, Environmental Conditions, and Water-Bath Temperature (Mean ± SD; N = 18)

Variable	Condition	
	Full American Football Uniform[a]	Control Uniform[b]
Exercise time to 39.5°C, min	41.7 ± 7.7	52.0 ± 10.9
Preimmersion water-bath temperature, °C	9.82 ± 0.14	9.85 ± 0.15
Postimmersion water-bath temperature, °C[c,d]	10.41 ± 0.16	10.59 ± 0.30
Environmental chamber temperature, °C	39.9 ± 0.4	40.1 ± 0.6
Environmental chamber relative humidity, %	34 ± 3	35 ± 3

[a] In the full American football uniform condition, each participant wore undergarments; shorts; crew socks; a T-shirt; jersey; game pants; padding over the knees, thighs, and tailbone; helmet; and shoulder pads.
[b] In the control uniform condition, each participant wore undergarments, crew socks, shorts, and a T-shirt that was removed before cooling.
[c] Full uniform condition after immersion < control uniform condition after immersion ($P < .05$).
[d] Full uniform condition and control uniform condition after immersion > full uniform condition and control uniform condition before immersion, respectively ($P < .05$).

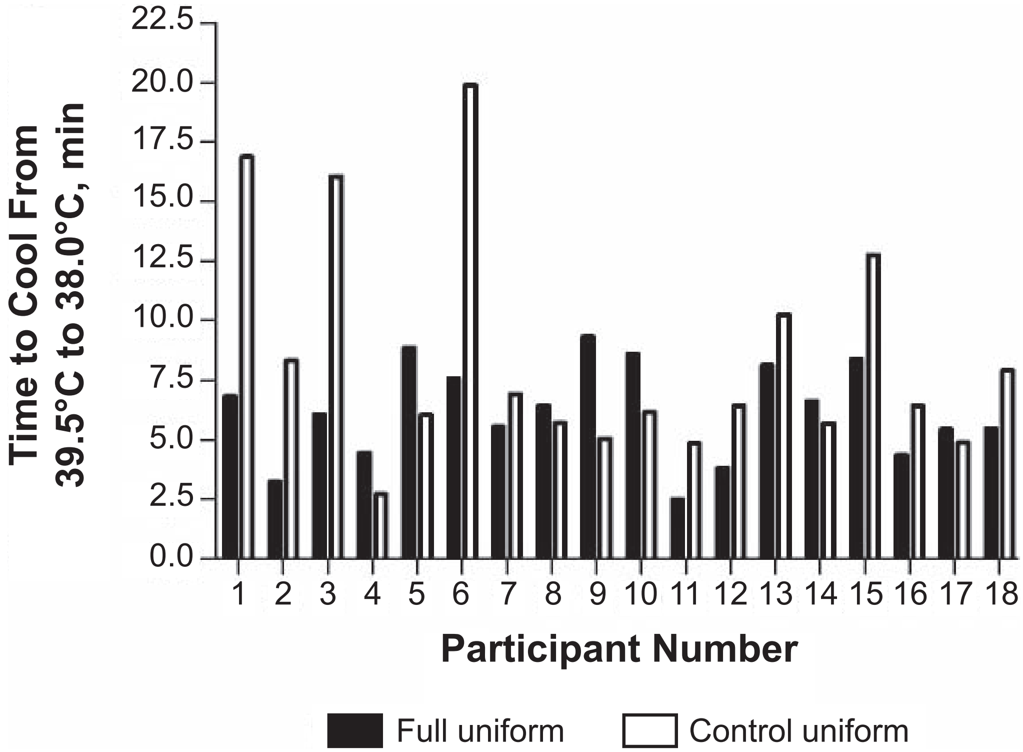

Figure 1. Time to cool from 39.5°C to 38.0°C for the 18 participants while wearing either a full American football uniform or control uniform.

concrete cinderblocks in the bath to help keep them immersed up to their necks. This was especially necessary on full-uniform days because of the buoyancy of the shoulder pads. The water bath was kept in the environmental chamber to minimize transfer time and to simulate the ambient conditions an athlete might experience while being cooled at an outdoor athletic event in the heat. The water bath was stirred every minute by tracing the athlete's body as close to the skin as possible with a metal rod. Participants remained in the water bath until T_{rec} was 38.0°C. We continuously monitored T_{rec} during cooling and recorded it every 30 seconds. The exact time to reduce T_{rec} to 38.0°C was recorded.

When T_{rec} reached 38.0°C, participants exited the water bath and sat in the environmental chamber for 30 minutes. All equipment and clothing worn during CWI were also worn during recovery. We recorded T_{rec} every 5 minutes. Participants air dried during recovery. After the 30-minute recovery period, the environmental chamber conditions were recorded, and participants exited the chamber, removed the football equipment, towel dried, were weighed nude, and were excused. No fluids were given to the athletes at any time.

Statistical Analysis

Separate dependent *t* tests were used to determine if differences existed between equipment conditions for urine specific gravity, environmental chamber temperature and humidity, and time needed to cool T_{rec} to 38.0°C. Data were assessed for skewness, kurtosis, and omnibus normality to ensure normal distribution. Skewness normality ($P = .11$), kurtosis normality ($P = .73$), and omnibus normality ($P = .26$) indicated no violation of normality existed.

We used separate repeated-measures analyses of variance to determine if differences existed in T_{rec} and water-bath temperatures between control and full uniforms. Sphericity was assessed with the Mauchly test. Greenhouse-Geisser adjustments to *P* values and degrees of freedom were made when sphericity was violated. Normality was assessed using Shapiro-Wilk tests. When we observed interactions or main-level effects, we used Tukey-Kramer multiple-comparison tests to identify differences between uniform conditions at each time point. The α level was set at .05. We used Number Cruncher Statistical Software (version 2007; NCSS, Kaysville, UT) for statistical analyses.

RESULTS

Data are given as means and standard deviations. Participants self-reported compliance with all pretesting instructions and were euhydrated before testing ($t_{17} = 0.12$, $P = .91$; Table 2). Environmental chamber temperature ($t_{17} = -1.2$, $P = .25$) and relative humidity ($t_{17} = -1.1$, $P = .30$) were similar between conditions (Table 4). We observed an interaction between equipment condition and time for water-bath temperature ($F_{1,17} = 7.7$, $P = .01$; Table 4). Initial water-bath temperature between conditions was similar ($P > .05$). However, postimmersion water-bath temperature in both conditions was higher than preimmersion temperatures ($P < .05$). Postimmersion water-bath temperature was higher with the control than the full uniform ($P < .05$).

Participants cooled to 38.0°C faster in the full uniform (6.19 ± 2.02 min) than in the control uniform (8.49 ± 4.78 min; $t_{17} = -2.1$, $P = .03$; effect size = 0.48; Figure 1) corresponding to T_{rec} cooling rates of $0.28°C·min^{-1} \pm 0.12°C·min^{-1}$ and $0.23°C·min^{-1} \pm 0.11°C·min^{-1}$, respec-

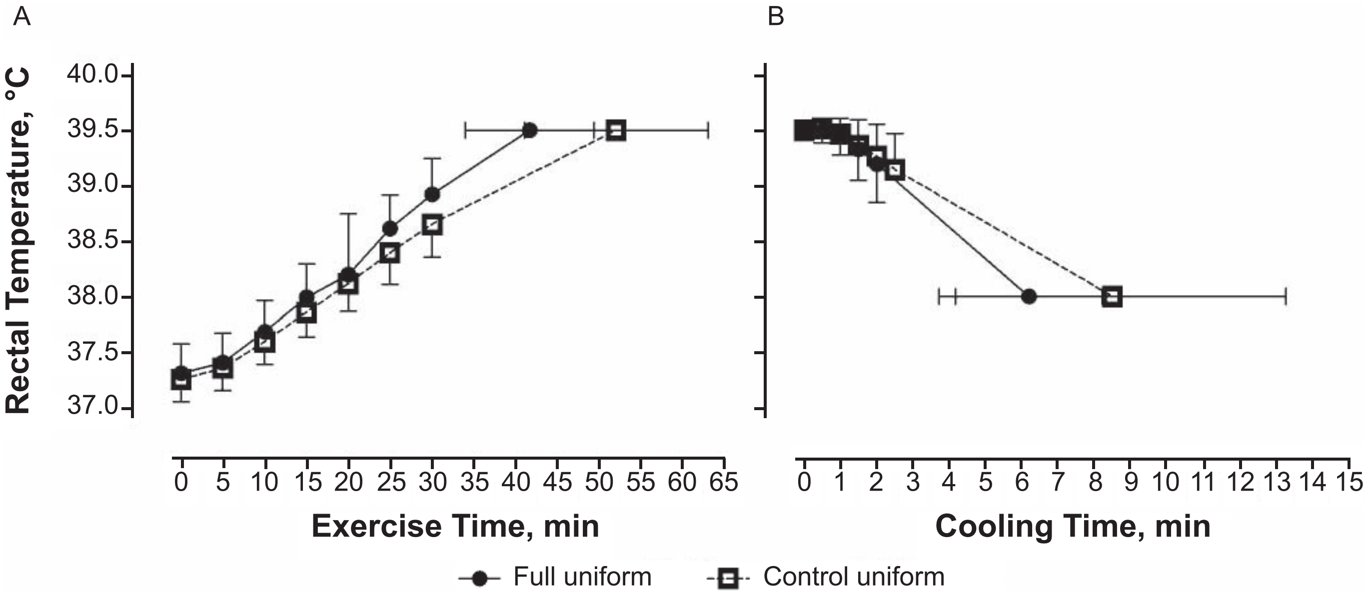

Figure 2. Rectal temperatures (mean ± SD) during A, exercise, and B, cold-water immersion for participants wearing a full American football uniform or control uniform. Exercise and cold-water–immersion durations differed among participants. Thus, the data are shown until the shortest exercise and cold-water–immersion duration common to all 18 participants. The final data point is the average time for participants to reach 39.5°C (A) and 38.0°C (B). The x error bars are the SDs for the times necessary to reach 39.5°C or 38.0°C.

tively ($t_{17} = 1.6$, $P = .07$; effect size = 0.44). We report T_{rec} during exercise and cooling for descriptive purposes (Figure 2).

We observed no interaction between equipment condition and time for postimmersion T_{rec} ($F_{1,17} = 0.6$, $P = .59$) or main effect for equipment condition ($F_{1,17} = 0.7$, $P = .42$). However, T_{rec} continued to decrease over the 30 minutes after immersion ($F_{1,17} = 188.5$, $P < .001$; Figure 3). The T_{rec} at 0 minutes after immersion was higher than at all other postimmersion times ($P < .05$). Similarly, T_{rec} at 5 minutes after immersion was higher than at 10, 15, 20, 25, and 30 minutes after immersion ($P < .05$). Finally, T_{rec} at 10 minutes after immersion was higher than at 15, 20, 25, and 30 minutes after immersion ($P < .05$).

DISCUSSION

Three clinically important points may be learned from our investigation. First, removing American football equipment may not be necessary before CWI in athletes with EHS. This is helpful if the football equipment is difficult to remove or the athlete's treatment is unusually delayed. Second, T_{rec} cooling rates of athletes with hyperthermia wearing full uniforms were well above minimally acceptable cooling rates (ie, $>0.08°C·min^{-1}$).[2] Third, wearing the full uniform after immersion did not result in more overcooling than wearing the control uniform. These results increase our understanding of the beneficial effects of CWI treatment in EHS specific to American football players.

The 2.3-minute difference in cooling times between conditions was moderately clinically important (effect size = 0.48). We propose 4 reasons why athletes with hyperthermia cooled faster in a full uniform. First, whereas we did not measure skin temperature, it was likely higher during the full uniform than the control uniform at the onset of cooling. Several authors[11,21,22,33] have observed that wearing protective clothing or a full uniform during exercise in hot conditions results in higher skin temperatures than when less clothing is worn. Differences in skin temperatures between the full and control uniform can range from 0.7°C to 4.5°C, with the greatest differences occurring in skin located under equipment (eg, abdomen, thigh, back).[11,21,22] Heat loss is highest when the temperature gradient between the water and body is greatest,[13,20] and the full uniform does not impede the access of cold water to the skin. The rate of temperature increase in the water bath supported this hypothesis (full uniform = $0.094°C·min^{-1}$, control uniform = $0.087°C·min^{-1}$). The longer CWI durations in the control uniform accounted for the higher postimmersion water-bath temperatures. Second, reflexive peripheral vasoconstriction and decreases in peripheral blood flow likely occurred to a lesser extent with the full uniform because of the higher skin temperatures and the presence of a layer of clothing covering the skin. This reflexive superficial vasoconstriction, likely occurring more with the control uniform, would direct blood flow from the skin to the core to protect the internal organs,[9] slowing cooling and resulting in longer immersion times.[20] However, even with the control uniform, our T_{rec} cooling rates were still considered ideal (ie, $>0.15°C·min^{-1}$).[2] Thus, we agree with other authors[9,20] that skin vasoconstriction during CWI should not be used as a reason to avoid CWI in treating EHS. Third, whereas we did not quantify shivering onset and intensity, participants in the control uniform may have experienced more shivering, or preshivering, because of greater direct skin exposure to the cold water. Preshivering and shivering increase muscular tone and contraction, in turn increasing metabolic heat and, thereby slowing the rate of cooling.[20] Proulx et al[20] observed shivering in almost all (6 of 7) of their participants with hyperthermia when water temperature was kept at 8°C or 14°C. Shivering likely contributed to the longer immersion times at these temperatures because the heart rate was higher when participants were

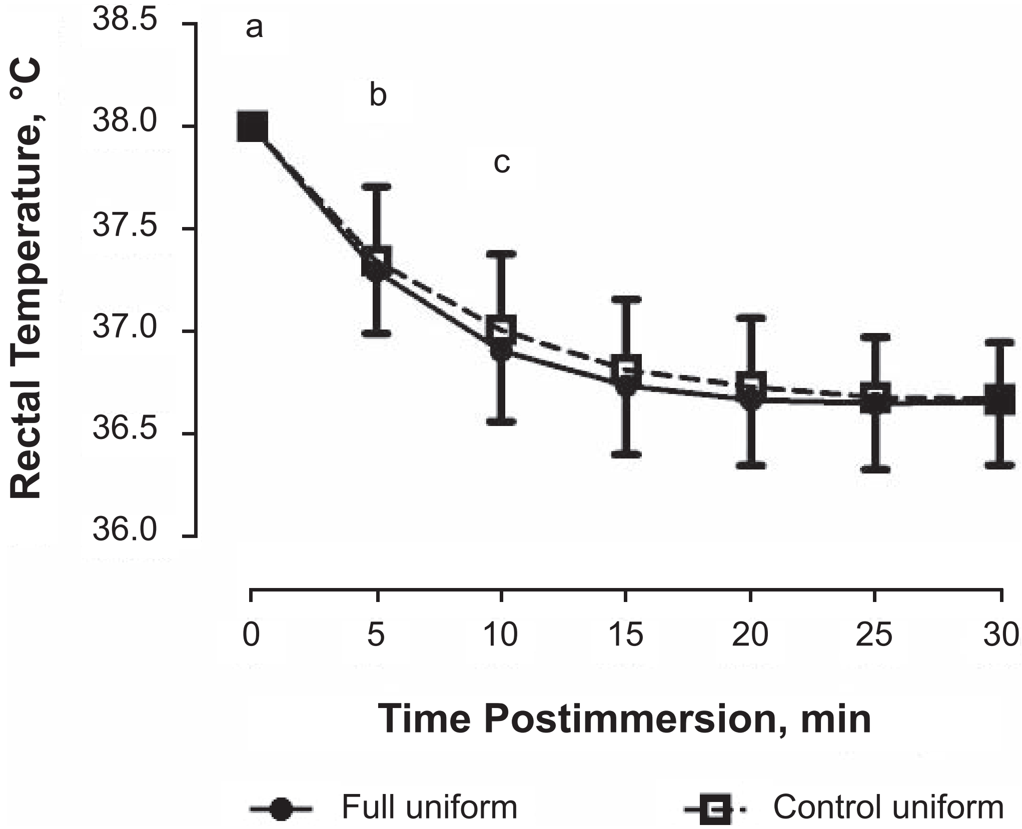

Figure 3. Rectal temperatures over 30 minutes after immersion between equipment conditions (mean ± SD). [a] Indicates 0 minutes > all other times. [b] Indicates 5 minutes > 10, 15, 20, 25, and 30 minutes. [c] Indicates 10 minutes > 15, 20, 25, and 30 minutes. The α level was set at .05 (N = 18).

cooled in the 8°C bath than in the 14°C bath.[20] Anecdotally, few (if any) of our participants experienced shivering when wearing the full uniform. Assuming that skin temperatures were higher at the onset of cooling in the full uniform, the shivering response would have been minimized (or absent) and may not have impaired cooling during full uniform, but it would have affected T_{rec} cooling in the control uniform.[20] However, shivering is not a reason to avoid CWI, as cooling rates in both conditions were ideal for treating persons with hyperthermia.[2] Finally, whereas convection is the dominant method of heat transfer during CWI, heat may have been transferred via conduction between the skin and uniform in the full uniform simply because more objects were in direct contact with the body. Overall, wearing the full uniform did not impede T_{rec} cooling.

The second major observation in our study was that T_{rec} cooling rates were high ($0.28°C\cdot min^{-1} \pm 0.12°C\cdot min^{-1}$) when participants with hyperthermia wore the full uniform during CWI. In a recent systematic review, McDermott et al[2] concluded that cooling rates between $0.08°C\cdot min^{-1}$ and $0.15°C\cdot min^{-1}$ were "acceptable," whereas anything greater than $0.16°C\cdot min^{-1}$ was "ideal" for treating persons with EHS. Therefore, T_{rec} cooling rates in the full uniform were excellent and likely the result of our aggressive stirring protocol, participants' modest body fat percentages, and other reasons we have outlined. It is interesting that although we observed different CWI times between conditions, cooling rates did not differ. However, the estimated effect size for our cooling rates indicated that the differences observed were moderately clinically important (effect size = 0.44).

An important consideration when treating persons with EHS is the time needed to initiate treatment.[23] The most efficient means of cooling football athletes with hyperthermia should be determined to ensure proper T_{core} cooling within the "golden half hour" advocated by researchers.[8,34,35] Current recommendations call for CWI to be initiated within 10 minutes of EHS recognition.[8,13,34] If clinicians implement CWI in fully equipped athletes with hyperthermia, it may be necessary to keep the body submerged (eg, gently holding the upper body under water while ensuring that the airway stays patent). Given that other cooling modalities (eg, ice packs) are less effective than CWI at rapidly lowering T_{rec},[2] we do not recommend cooling the fully equipped American football athlete with any other cold modality.

A secondary aim of our study was to determine if wearing the full uniform produced a greater postimmersion hypothermic afterdrop. Whereas overcooling and developing hypothermia is a concern with CWI,[15,24,25] our hypothesis was rejected. None of our participants approached a dangerous level of hypothermia ($T_{rec} < 35°C$) in either the full or control uniform after CWI. Moreover, T_{rec} between uniform conditions confirmed no advantage or disadvantage to wearing the full uniform during recovery. Thus, if a fully equipped American football athlete with hyperthermia is cooled via CWI, the equipment may be removed when T_{rec} is lowered to a safe value (eg, 38.0°C to 38.6°C).[15]

Whereas our results suggested that the full uniform can remain in place during CWI, emergency providers may have other reasons for wanting to remove equipment. The protective equipment used in American football also, unfortunately, serves as a barrier to medical assessment and treatment. If patients experience cardiac difficulties because of their severe hyperthermia, responders must remove wet clothing and equipment before they can apply life-saving maneuvers (eg, cardiopulmonary resuscitation or automated external defibrillator). However, the incidence of cardiac emergencies due to CWI is likely very low to nonexistent given the near 100% survival rate of persons with EHS when properly treated with CWI.[24] Similarly, airway management is not possible with a helmet and face mask in place. Whereas current EHS-related position statements do not specifically mention the need for airway management when treating EHS,[3,36,37] clinicians should always ensure the patency of the airway when treating patients with life-threatening conditions. We chose to keep the helmet on during CWI to maximize the equipment worn during cooling, but nothing precludes clinicians from removing it in a clinical EHS cooling scenario. Removing the helmet during CWI would simplify the assessment of pupillary response and return to consciousness.

The following limitations were inherent to our investigation. First, participants supplied and wore the same clothing each day of testing. Therefore, the exact material composition of the clothing likely differed among them. Second, the proximity of the treadmill to the CWI bath probably did not represent the proximity, and hence time of transfer, to CWI in an actual EHS scenario. Third, we tested only 1 combination of football equipment and uniform in an otherwise healthy, recreational male population with less body fat than football athletes (eg, linemen) who are typically at risk of EHS. Our results may not be generalizable to other protective equipment or clothing options, different ages, or female football participants with EHS. Fourth, given that we continuously assessed T_{rec}, the time-to-transfer procedure did not reflect the time or process of inserting a rectal temperature probe between exercise and CWI. Fifth, 3 participants seemed to cool much more slowly in the control uniform, thereby affecting the average cooling duration for the control uniform. Given that we used a counterbalanced, crossover design, the physiology and demographics (eg, body-fat percentage, body density, body surface area) of these participants would have been approximately the same each day. Thus, external factors other than water-bath temperature (full uniform = 9.8°C, control uniform = 9.9°C), such as the presence, intensity, or duration of shivering or differences in the magnitude of the water-bath stirring, likely caused the differences between testing conditions. Sixth, practical (eg, thermocouples pulling away from the skin during exercise and CWI) and philosophical (eg, creation of a microenvironment when occlusive dressing or tape covers skin thermocouples) limitations prevented us from measuring skin temperature and, thus, heat flux. Researchers[11,21,22,33] have strongly suggested that skin temperature is higher when people wear protective clothing or full American football uniforms during exercise in the heat. Thus, skin temperature likely was higher in our study as well. Other scientists may want to confirm our hypothesis that skin temperature was higher during CWI in full uniform with more sensitive and valid measures of skin temperature.

CONCLUSIONS

The T_{rec} cooling in participants wearing the full uniform was excellent and did not result in excessive overcooling after immersion. Treatment protocols specific to American football players should be developed to improve outcomes and ensure the most efficient means of treating football athletes with hyperthermia. Future research is needed on the effect of wearing a full uniform during CWI in EHS situations and in heavier athletes with more adipose tissue (eg, linemen). If observations are similar in these scenarios, future position statements on the care of football players with EHS may need to reflect the new data.

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