Cold-Water Immersion for Hyperthermic Humans Wearing American Football Uniforms

Kevin C. Miller, PhD, AT, ATC*; Erik E. Swartz, PhD, ATC, FNATA†; Blaine C. Long, PhD, AT, ATC*

*School of Rehabilitation and Medical Sciences, Central Michigan University, Mount Pleasant; †Department of Kinesiology, University of New Hampshire, Durham

**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 (Trec) cooling or exacerbates hypothermic afterdrop.

**Objective:** To determine the time to cool Trec 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 Trec 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 m²).

**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 Trec 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 Trec to 38.0°C (in minutes) was recorded. We measured Trec (°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 Trec.

**Results:** The Trec cooled to 38.0°C in 6.19 ± 2.02 minutes in full uniform and 8.49 ± 4.78 minutes in control uniform (t17 = −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 (t17 = 1.6, P = .07, effect size = 0.44). The Trec postimmersion recovery did not differ between conditions over time (F1,17 = 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

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Exertional heatstroke (EHS) is a medical emergency diagnosed when body core temperature (Tcore) 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 Tcore greater than 40°C.4–7 Therefore, the immediate treatment priority is to initiate cold-water immersion (CWI) and lower Tcore 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 pads; or (3) shorts, crew socks, shoes, and shirt.11,12

The National Athletic Trainers’ Association,8 American College of Sports Medicine,13 and expert consensus14 have recommended removing clothes and equipment before CWI if an American football athlete has EHS. These recommen-
Table 1: Participant Demographics (N = 18)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>22 ± 3</td>
</tr>
<tr>
<td>Height, cm</td>
<td>178.8 ± 6.8</td>
</tr>
<tr>
<td>Body mass index</td>
<td>25.7 ± 3.5</td>
</tr>
<tr>
<td>Sum of skinfolds, mm</td>
<td>46.6 ± 12.3</td>
</tr>
<tr>
<td>Body density, g/cc</td>
<td>1.07 ± 0.01</td>
</tr>
<tr>
<td>Body fat, %</td>
<td>13 ± 4</td>
</tr>
<tr>
<td>Body surface area, m²</td>
<td>2.0 ± 0.2</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Full American Football Uniforma</th>
<th>Control Uniformb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-exercise urine specific gravity</td>
<td>1.006 ± 0.005</td>
<td>1.006 ± 0.005</td>
</tr>
<tr>
<td>Pre-exercise body mass, kg</td>
<td>82.3 ± 12.6</td>
<td>82.5 ± 12.9</td>
</tr>
<tr>
<td>Postrecovery body mass, kg</td>
<td>81.1 ± 12.5</td>
<td>81.3 ± 12.7</td>
</tr>
<tr>
<td>Sweat rate, L h⁻¹</td>
<td>1.6 ± 0.4</td>
<td>1.5 ± 0.4</td>
</tr>
<tr>
<td>Hydration, %</td>
<td>1.3 ± 0.3</td>
<td>1.5 ± 0.4</td>
</tr>
</tbody>
</table>

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.

... 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; (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.

Methods

Experimental Design

We used a crossover design with repeated measures to guide data collection. To determine how equipment affects Trec cooling times, our independent variable was equipment condition (full, control). To determine how equipment affects Trec recovery, the independent variable was 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 Trec (in degrees Celsius).

Participants

Based on the assumption that a 5-minute difference in cooling time is clinically meaningful, 15 participants were needed to detect a difference at 80% power with an α level...
We continuously monitored $T_{rec}$ during exercise to determine when participants reached the thermal threshold. Environmental chamber conditions were also recorded immediately after exercise.

Environmental chamber temperature, °C 34.6 ± 0.4
Environmental chamber relative humidity, % 52.0 ± 0.3

Participants entered an environmental chamber and stood 20 cm past the anal sphincter. Next, they put on either a full American football uniform or undergarments. Full American football uniform wore undergarments, shorts, crew socks, T-shirt, tennis shoes, helmet, and shoulder pads. Undergarments, shorts, crew socks, T-shirt, tennis shoes, jersey, game pants, knee pads, thigh pads, tailbone pads, helmet, and shoulder pads were worn on the control uniform condition before immersion, respectively ($P < .05$).

Table 3. Clothing and Equipment Worn During Exercise or Cooling

<table>
<thead>
<tr>
<th>Equipment Condition</th>
<th>Clothing and Equipment Worn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control uniform</td>
<td>Undergarments, shorts, crew socks, T-shirt, and tennis shoes</td>
</tr>
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<td>Full American football uniform</td>
<td>Undergarments, shorts, crew socks, T-shirt, tennis shoes, jersey, game pants, knee pads, thigh pads, tailbone pad, helmet, and shoulder pads</td>
</tr>
</tbody>
</table>

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 between the shorts and football pants and kept in place by the pressure exerted by the pant belt.

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 into the pouches in the game pants.

l Riddell Revolution Speed helmet with G2BD mask (Easton-Bell Sports, Van Nuys, CA) with standard padding inside the helmet.

m SP Mr. DZ Linemans football shoulder pads (Douglas Pads & Sports, Inc, Houston, TX) in size XL.

summed and used to estimate body density$^{10}$ 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. Researchers secured insulated thermocouples (model PT-6; 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 the start of immersion, respectively ($P < .05$).

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</tr>
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<td>Undergarments, shorts, crew socks, T-shirt, tennis shoes, jersey, game pants, knee pads, thigh pads, tailbone pad, helmet, and shoulder pads</td>
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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 the start of immersion, respectively ($P < .05$).

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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Full American Football Uniforma</th>
<th>Control Uniformb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise time to 39.5°C, min</td>
<td>41.7 ± 7.7</td>
<td>52.0 ± 10.9</td>
</tr>
<tr>
<td>Preimmersion water-bath temperature, °C</td>
<td>9.82 ± 0.14</td>
<td>9.85 ± 0.15</td>
</tr>
<tr>
<td>Postimmersion water-bath temperature, °C</td>
<td>10.41 ± 0.16</td>
<td>10.59 ± 0.30</td>
</tr>
<tr>
<td>Environmental chamber temperature, °C</td>
<td>39.9 ± 0.4</td>
<td>40.1 ± 0.6</td>
</tr>
<tr>
<td>Environmental chamber relative humidity, %</td>
<td>34 ± 3</td>
<td>35 ± 3</td>
</tr>
</tbody>
</table>

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 ($P < .05$).
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 ± 0.12°C min⁻¹ and 0.23°C min⁻¹ ± 0.11°C min⁻¹, respec-

![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.](http://meridian.allenpress.com/jat/article-pdf/50/8/792/1457640/1062-6050-50_6_01.pdf)
We propose 4 reasons why athletes with hyperthermia cooled faster in a full uniform. Exercise and cold-water–immersion durations differed among participants. Thus, the data are shown separately (t₁,₇ = 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} (F₁,₁₇ = 0.6, P = .59) or main effect for equipment condition (F₁,₁₇ = 0.7, P = .42). However, T_{rec} continued to decrease over the 30 minutes after immersion (F₁,₁₇ = 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 (i.e., >0.08°C·min⁻¹).³ Third, wearing the full uniform after immersion did not result in more overheating 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 authors¹¹,²¹,²²,³³ 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 (e.g., 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 (i.e., >0.15°C·min⁻¹).² Thus, we agree with other authors⁹,²⁰ 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 al²⁰ 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
cooled in the 8°C bath than in the 14°C bath. 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 Trec cooling in the control uniform. However, shivering is not a reason to avoid CWI, as cooling rates in both conditions were ideal for treating persons with hyperthermia. 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 Trec cooling.

The second major observation in our study was that Trec cooling rates were high (0.28°C/min ± 0.12°C/min) when participants with hyperthermia wore the full uniform during CWI. In a recent systematic review, McDermott et al concluded that cooling rates between 0.08°C·min⁻¹ and 0.15°C·min⁻¹ were “acceptable,” whereas anything greater than 0.16°C·min⁻¹ was “ideal” for treating persons with EHS. Therefore, Trec 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. The most efficient means of cooling football athletes with hyperthermia should be determined to ensure proper Tcore cooling within the “golden half hour” advocated by researchers. Current recommendations call for CWI to be initiated within 10 minutes of EHS recognition. 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 Trec, 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, our hypothesis was rejected. None of our participants approached a dangerous level of hypothermia (Trec < 35°C) in either the full or control uniform after CWI. Moreover, Trec 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 Trec is lowered to a safe value (eg, 38.0°C to 38.6°C).

Figure 3. Rectal temperatures over 30 minutes after immersion between equipment conditions (mean ± SD). Indicates 0 minutes > all other times. Indicates 5 minutes > 10, 15, 20, 25, and 30 minutes. Indicates 10 minutes > 15, 20, 25, and 30 minutes. The α level was set at .05 (N = 18).
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. 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 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 $T_{\text{rec}}$, 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 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 $T_{\text{rec}}$ 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.

**ACKNOWLEDGMENTS**

We thank Michael McPike, MS; Greg McGillvary, MA, ATC; and Joseph Fox, MA, ATC, for donating the equipment for this study and Mr Tyrel Dingman and Mr Jon Burke for their assistance with data collection.

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Address correspondence to Kevin C. Miller, PhD, AT, ATC, Athletic Training Program, Central Michigan University, 1208 Health Professions Building, Mount Pleasant, MI 48859. Address e-mail to mille5k@cmich.edu.