Effectiveness of Cold Water Immersion in the Treatment of Exertional Heat Stroke at the Falmouth Road Race

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ABSTRACT

DEMARTINI, J. K., D. J. CASA, R. STEARNS, L. BELVAL, A. CRAGO, R. DAVIS, and J. JARDINE. Effectiveness of Cold Water Immersion in the Treatment of Exertional Heat Stroke at the Falmouth Road Race. *Med. Sci. Sports Exerc.*, Vol. 47, No. 2, pp. 240–245, 2015. **Purpose**: This study aimed to investigate the effectiveness (speed of cooling and survival rates) of cold water immersion (CWI) in the treatment of patients with exertional heat stroke (EHS). Secondly, this study aimed to compare cooling rates on the basis of gender, age, and initial rectal temperature (T_r). **Methods**: Eighteen years of finish line medical tent patient records were obtained from the exertional heat illness treatment area at the Falmouth Road Race. Study participants included patients with EHS who were treated with CWI in the medical tent. The number of EHS cases was recorded for each year, and incidence was established on the basis of the number of finishers. Overall cooling rate and differences between initial T_r, age, and sex were evaluated. **Results**: A total of 274 cases of EHS was observed over the 18 yr of collected data. A mean of 15.2 ± 13.0 EHS cases per year was recorded, with an overall incidence of 2.13 ± 1.62 EHS cases per 1000 finishers. The average initial T_r was 41.44°C ± 0.63°C, and the average cooling rate for patients with EHS was 0.22°C·min^{-1} ± 0.11°C·min^{-1}. CWI resulted in a 100% survival rate for all patients with EHS. No significant interactions between cooling rate and initial T_r (P = 0.778), sex (P = 0.89), or age (P = 0.70) were observed. **Conclusions**: CWI was found to effectively treat all cases of EHS observed in this study. CWI provided similar treatment outcomes in all patients, with no significant differences noted on the basis of initial T_r, age, or sex. On the basis of the 100% survival rate from EHS in this large cohort, it is recommended that immediate (on site) CWI be implemented for the treatment of EHS. **Key Words:** HYPERTHERMIA, EXERTIONAL HEAT STROKE, COLD WATER IMMERSION, COOLING RATE

Exertional heat stroke (EHS) is one of the leading causes of death among athletes (5,22,26). Data from the University of North Carolina National Center for Catastrophic Injury have shown drastic increase in the number of deaths from EHS over the last 5-yr reporting period (2004–2009) compared with that in previous reporting periods (26,27,37). Furthermore, during the last 2 yr (2011–2012), these deaths continue to show an increasing trend (23). Many of these deaths occur during organized sport participation, such as high school football practice or collegiate conditioning sessions, when appropriate medical personnel (i.e., certified athletic trainer) are not present. The highest recorded incidence of EHS has been encountered at the Falmouth Road Race, with a reported 1–2 EHS cases for every 1000 entrants (7). However, despite the high occurrence of EHS cases during this event, no deaths have been reported.

Studies and case reports have consistently shown that the time a person's core body temperature is above 40°C predicts the outcome of the EHS case (8,12,20,21,32). Therefore, the primary goal with any patient with EHS is to cool him/her as immediately and rapidly as possible. Substantial evidence has demonstrated (1,4,9,10,14,20,21,29,32,34) or supported (3,4,12,13,25) such use of cold water immersion (CWI) for treatment of EHS. This is largely due to the superior cooling efficacy of CWI established by various research studies (2,10,17,24,25,30,31). CWI is superior to other cooling methods because of its high thermal conductivity and high body surface contact area (38). In addition, various reports have been made on survival from EHS when immediate CWI was used (7,21,38) whereas reports of death have occurred from delayed or inappropriate care (18,21,32,38).

It is suggested that for effective treatment of EHS, a minimum cooling rate of 0.1°C·min^{-1}–0.2°C·min^{-1} (0.18°F·min^{-1}–0.36°F·min^{-1}) should be obtained if cooling occurs immediately or a rate of 0.15°C·min^{-1} (0.27°F·min^{-1}) if cooling is delayed (13,37). With such cooling rates, it is

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possible for patients with EHS to be cooled to normothermic temperatures in as quickly as 15 minutes.

Although there are current data to support superior cooling rates of CWI (2,10,17,24,25,30,31) and data to support the devastating results of inappropriate care (18,21,32,38), no large-scale publication documenting the success of CWI with real patients of EHS has been made. This report describes 18 yr of EHS data from the Falmouth Road Race. These data include incidence of EHS, demographic data of patients with EHS, signs and symptoms at time of the EHS episode, cooling rates during treatment, and outcomes of these EHS cases. The purpose of this study was to investigate the effectiveness of CWI in the treatment of EHS. In addition, we sought to compare cooling rates on the basis of the patient's gender, age, and initial rectal temperature (T_r) in a clinical setting.

METHODS

Study design. We studied cases of EHS that occurred at the Falmouth Road Race. The Falmouth Road Race is a 7-mile (11.26 km) point-to-point race held annually on the second Sunday of August in Falmouth, MA (41°52′ N, 70°67′ W). The average weather conditions, according to METAR (Meteorological Aerodrome Report) from the Cape Cod Coast Guard Air Station, for the races studied were an ambient temperature of 23.3°C ± 2.5°C and a relative humidity of 70% ± 16% for the duration of the race. The race begins at 10:00 a.m. with approximately 10,000 runners, ranging from elite to novice status.

Race participants. Finish line medical tent patient records were obtained for years in which information was available (18 yr total), as follows: 1984,1989, 1992–1994, 1996–1998, 2001, and 2003–2011. Patient information was selected for inclusion on the basis of a recorded initial or maximal T_r greater than or equal to 40°C and a recorded diagnosis of EHS. The total number of cases of EHS was recorded for each year, and incidence was established on the basis of number of finishers when available (1997–1998, 2001, and 2003–2011).

Diagnosis criteria for exertional heat illness. Runners who presented to the finish line medical tent with signs and symptoms of exertional heat illness (EHI) were triaged to a specific treatment area. This is the only medical tent at the Falmouth Road Race, and thus, all patients were treated at this location. Upon entrance to the EHI treatment area, the patient's T_r, HR, and blood pressure (BP) were recorded. Common signs of EHI such as history of collapse, ashen skin, and alterations in pulse were also noted. Once in the treatment area, cases of EHS were diagnosed when T_r is >40°C (104°F) and the patient presented with CNS dysfunction, often including signs such as irritability, aggressiveness, confusion, or unconsciousness. Once the diagnosis of EHS was made, patients were immediately immersed in a tub of ice water. Specific data regarding time from collapse to initiation of treatment were not available; however, it can be noted from direct experience that almost all cases involved treatment within 2 min after collapse.

Treatment for EHS. When diagnosed with EHS (T_r, >40°C (104°F) with associated CNS dysfunction), patients were immediately cooled via CWI in 50-gal tubs. Immersion tubs were filled with water before the finish of the race, and ice was added to each tub as needed to maintain a water temperature of approximately 10°C (50°F). Upon diagnosis of EHS, the patient was immediately immersed in the tub in a seated position. If the patient's arms or legs were not able to completely fit in the tub (for most patients the entire torso, upper thighs, and lower two-thirds of the arms were completely immersed), wet ice towels were constantly rotated over the legs, arms, neck, and head. T_r was continuously monitored, and T_r, HR, and BP were recorded every 2 min for the duration of the treatment period. Once patient's T_r dropped below 38.8°C (102°F), they were removed from the immersion tub to prevent overcooling and were sent to the recovery area for monitoring. Patients were then monitored to ensure regulation and maintenance of core body temperature and absence of signs of sequelae and were released when deemed appropriate by a physician. Total immersion time and resulting cooling rate were calculated for those patients who had complete treatment files (i.e., initial T_r, T_r at the end of immersion, and immersion time) (n = 179). Permission to use medical record data was approved by the university's institutional review board.

Statistical analysis. Descriptive statistics are presented as means ± SD. One-way ANOVA and Mann–Whitney U tests were used to assess group differences between male and female patients with EHS. ANOVA regression analysis was used for comparison of cooling rate and T_r. One-way ANOVA with Tukey *post hoc* analysis was performed to evaluate cooling rate by diagnosis, sex, and age. Significance was set *a priori* at an alpha level of $P < 0.05$. Statistical analyses were performed using PASW Statistics version 18 for Mac (IBM SPSS Statistics, Chicago, IL).

RESULTS

Two-hundred and seventy-four cases of EHS are presented in this study. Profiles of patients with EHS whose records contained detailed information regarding signs and symptoms are reported in Table 1 (n = 258). Total cases of EHS and incidence rate by year are shown in Table 2. A mean of 15.2 ± 13.0 EHS cases per year was recorded over the 18 yr studied. An overall incidence of 2.13 ± 1.62 EHS cases per 1000 finishers was calculated. The year 2003 served as the most extreme year in which 53 cases of EHS occurred with an incidence rate of 6.57 cases per 1000 finishers.

A comparison of initial T_r and cooling rate is presented in Figure 1 (n = 179). Average initial T_r for all patients with EHS was 41.44°C ± 0.63°C (range, 40.0°C–42.78°C (104.0°F–109.0°F)). The average cooling rate for all patients with EHS was $0.22°C\cdot min^{-1} \pm 0.11°C\cdot min^{-1}$. The regression analysis

TABLE 1. Profile of EHS cases by sex (mean ± SD).

	Male	Female
Age (yr)	34 ± 13 (n = 131)	29 ± 11[a] (n = 81)
Initial body temperature (°C)	41.4 ± 0.7 (n = 166)	41.2 ± 0.7[a] (n = 92)
Cooling rate (°C·min^{-1})	0.22 ± 0.12 (n = 110)	0.22 ± 0.10 (n = 69)
Systolic BP (mm Hg)	134 ± 35 (n = 61)	127 ± 29 (n = 23)
Diastolic BP (mm Hg)	58 ± 19 (n = 60)	50 ± 26 (n = 23)
Pulse (bpm)	121 ± 22 (n = 60)	120 ± 21 (n = 22)
Ashen skin	78.6% (n = 42)	60.0% (n = 10)
Home discharges[b]	94.4% (n = 107)	90.7% (n = 75)

revealed no significant interaction between initial T_r and cooling rate (r^2 = 0.0004, P = 0.778).

Cooling rate of patients with EHS by sex is presented in Figure 2 (n = 179). The average cooling rate for male patients with EHS (n = 110) was 0.22°C ± 0.12°C. The average cooling rate for female patients with EHS (n = 69) was 0.22°C ± 0.10°C. No significant difference existed in the cooling rate between males and females (P = 0.89).

Cooling rate by age group (n = 142; range, 13–65 yr) as divided into decades is presented in Figure 3. Cooling rates of patients with EHS between the ages of 11 and 20 yr (n = 26), 21 and 30 yr (n = 43), 31 and 40 yr (n = 36), 41 and 50 yr (n = 28), 51 and 60 yr (n = 8), and 61 and 70 yr (n = 1) were 0.24°C ± 0.12°C, 0.21°C ± 0.11°C, 0.20°C ± 0.10°C, 0.22°C ± 0.12°C, and 0.23°C ± 0.12°C, respectively. No significant difference existed in the cooling rate between age groups (P = 0.70).

DISCUSSION

The purpose of this study was to investigate the effectiveness of CWI in the treatment of EHS. In addition, we sought to compare cooling rates on the basis of the patients' initial T_r, sex, and age. This was the first study to report the effectiveness of CWI on a large number of patients with EHS. In addition, this was the first study to explore differences in cooling rate on the basis of the patient's demographic information. The primary findings were that CWI produced a 100% survival rate of all 274 patients with EHS and that cooling rate was not significantly impacted because of differences in initial T_r, sex, or age.

The Falmouth Road Race provides a unique opportunity to study EHS. This race is held annually in August, and therefore, environmental conditions (i.e., ambient temperature and relative humidity) are typically high. In addition, the relatively short distance of the race allows runners to maintain high exercise intensity, resulting in a large number and high incidence of EHS compared with that during longer-distance races (33,35). Because high exercise intensity is the leading predisposing factor for acquiring EHS (28,32,36) and high environmental conditions also play a significant role, EHS cases and incidence rate at the Falmouth Road Race are particularly high. The 18 yr of data from this race that are used in the present study are the most comprehensive database for EHI cases and treatment efficacy of EHS among runners.

It was first reported in 1989 that the Falmouth Road Race produces 1–2 EHS cases per 1000 entrants, accounting for 40% of the total patients treated in the medical tent (7). This is a 10-fold increase in the incidence of EHS compared with longer-distance races (33,35). The results from this study revealed an average of 15.3 ± 13.0 EHS cases per year, resulting in a slightly higher incidence rate than that previously reported at this race (7) (Table 2). The higher incidence at this race is likely due to the shorter distance (and therefore higher exercise intensity), as the contribution of environmental conditions between this race (16) and others that took place in a cooler environment (33,35) have been shown to be similar (approximately 70%). The specific influence of environmental condition on the incidence of EHS during the Falmouth Road race has previously been studied (16).

While moderate exercise-induced hyperthermia (37.2°C–38.9°C (99°F–102°F)) is normal, and even protective in that it triggers the body's sweating response, in the case of EHS (core body temperature greater than 40°C–40.5°C (104°F–105°F)), long-term neurological deficits and organ/tissue damage are possible with improper and/or delayed recognition and treatment because of the sustained inflammatory response associated with hyperthermia. Proper treatment for EHS has long been described as the "golden hour," highlighting the importance of rapid treatment within the first hour of EHS diagnosis (20). This recommendation was based on four case studies involving patients with EHS. Two of the cases involved immediate T_r assessment and rapid cooling within 1 h of collapse, resulting in successful release from the hospital with no reported sequelae,

TABLE 2. Heat stroke incidence by year.

Year	Heat Strokes	Heat Strokes per 1000 Finishers
1984	15	N/A
1989	3	N/A
1992	5	N/A
1993	5	N/A
1994	17	N/A
1996	15	N/A
1997	17	2.20
1998	8	1.11
2001	6	0.81
2003	53	6.57
2004	9	1.10
2005	24	3.19
2006	8	0.97
2007	26	2.92
2008	23	2.63
2009	14	1.58
2010	11	1.14
2011	15	1.38
Mean ± SD	15.3 ± 13.0	2.13 ± 1.62

N/A, not applicable: finisher data was not available for the years prior to 1997. Therefore, the ratio of heat strokes per 1000 finishers could not be calculated.

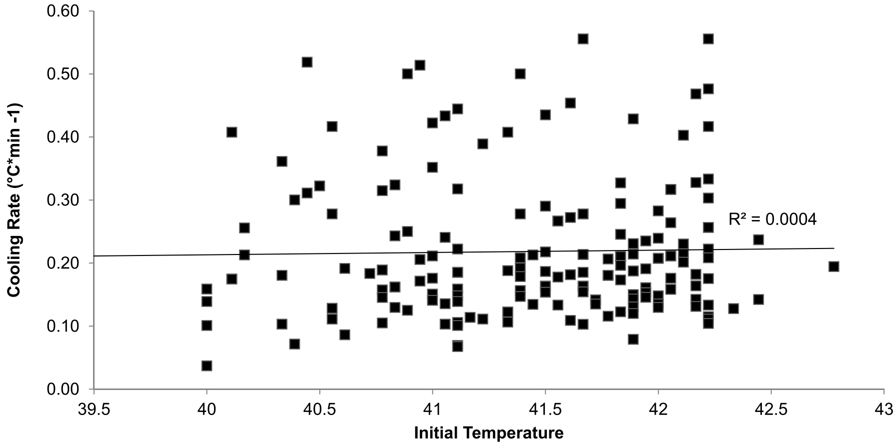

FIGURE 1—Cooling rate vs initial body temperature in patients who were diagnosed with EHS. R^2 = 0.0004, indicating no significant interaction between initial core body temperature (immediately before the initiation of cooling) and cooling rate (during treatment) ($P > 0.05$). The *solid horizontal line* shows average cooling rate of all patients with EHS.

whereas the other two involved improper recognition and delayed treatment, resulting in fatality (20). In addition, the cases of the two fatalities actually exhibited lower maximal T_r than those of the two survivors (20). This shows that the residual effects of elevated core body temperature depend on the duration, not necessarily the degree, of hyperthermia (6,11,14), and the risk of morbidity and mortality is greater the longer a patient's body temperature remains elevated above the critical threshold (40.0°C) (9).

The most effective way to decrease core body temperature is full-body CWI in a pool or tub (water temperature should be between 1°C (35°F) and 15°C (59°F)) because of the superior cooling rates demonstrated by this method (11,13–15). Other forms of cooling (i.e., cold water dousing with fans and ice water towels) may be used if CWI is not available; however, these methods decrease core body temperature at a slower rate compared with CWI (11,15,24,25). It is suggested that for effective treatment of EHS, a minimum cooling rate of 0.1°C·min^{-1}–0.2°C·min^{-1} (0.18°F·min^{-1}–0.36°F·min^{-1}) should be obtained (13,37). This has prompted researchers and clinicians to modify the "golden hour" motto to the "golden half-hour" (14). These reports have proven that when EHS is immediately treated via rapid whole-body cooling in which core body temperature is reduced below the critical threshold within 30 min of collapse, a 100% survival rate with limited or no sequelae has been reported (7,11,14,15). In the present study, an average cooling rate of 0.22°C·min^{-1} ± 0.11°C·min^{-1} was obtained for all patients with EHS. This is considered to be a superior cooling rate on the basis of the predescribed criteria (2) and when compared with those stated in previous reports (10).

In addition to observing general cooling rates in patients with EHS, we also sought to determine whether differences would arise on the basis of initial T_r. When considering the basic physiological principles of CWI and its effect on the thermoregulatory system, it would be reasonable to believe that those patients with higher maximal temperatures would exhibit faster cooling rates because of the wider temperature gradient between the patient and the water. However, despite having a wide range of initial T_r (40.0°C–42.78°C

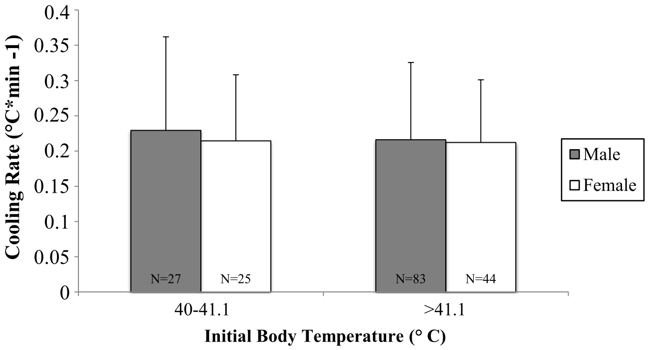

FIGURE 2—Cooling rate for both males and females grouped by initial core body temperature (immediately before the initiation of cooling). No significant differences occurred for rate of cooling (during treatment) between males and females regardless of initial body temperature ($P > 0.05$).

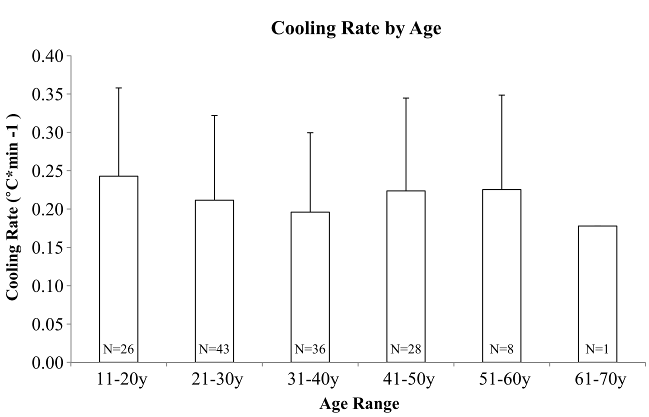

FIGURE 3—Cooling rate of subjects separated by age groups. No significant differences occurred for cooling rate of subjects on the basis of age range ($P > 0.05$).

(104.0°F–109.0°F)), we found no significant interaction between cooling rate and initial T_r (Fig. 1). This lends further support to the suggestion that an extreme initial core body temperature should not deter a clinician from immediate CWI treatment before hospital transport because even those patients with T_r of 109°F were successfully cooled via CWI. Therefore, the main difference in the treatment of patients with EHS whose core body temperatures are different is the time required for them to be in the immersion tub to successfully lower them to within a normothermic range.

In addition to initial T_r, potential differences in cooling rate based on demographic information were also explored. Despite a seemingly disproportionate number of young male patients with EHS, to our knowledge, no previous study has examined differences in cooling rates of patients with EHS on the basis of age and/or sex. The higher prevalence of EHS cases in this cohort is likely due to the familiar occurrence of EHS among high school and collegiate football players as well as in basic training of military recruits (23,26,27). Although observing a higher occurrence of EHS in men versus women in the current study, there were no significant differences in initial body temperature (41.4°C ± 0.7°C vs 41.2°C ± 0.7°C) or cooling rate (0.22°C ± 0.12°C vs 0.22 ± 0.10°C) (Table 1 and Fig. 2). Similarly, although the majority of patients with EHS in this study were between the ages of 21 and 40 yr, there were no observed differences in cooling rate among age groups (Fig. 3).

Similar to the case studies previously described, a recent study by Zeller et al. (38) reviewed the management of 32 cases of EHS. Of the 14 patients deemed as moderate-to-severe cases (on the basis of recovery time and degree of multiorgan failure), it was noted that treatment was delayed in all 14 patients and none of them were cooled immediately (before hospital transport), with two of those cases resulting in fatalities (38). The undesirable outcomes exhibited in this study were a direct result of improper recognition and/or treatment. The benefit of having a consistently high occurrence of EHS cases at the Falmouth Road Race is that proper prevention, recognition, and treatment strategies have been implemented (and modified, if necessary) to provide optimal care for patients with EHS. These strategies include prefilled immersion tubs, use of rectal thermometry, and rapid cooling via CWI. Perhaps most importantly, the time between collapse and commencement of treatment is rapid, usually occurring within minutes of the initial collapse. In the present study of 274 cases of EHS, this protocol has not only resulted in a 100% survival rate of patients with EHS but has also allowed 93% of the victims to be cleared for home discharge by a medical tent physician.

Several limitations were inherent in this study. Given the retrospective nature of the study design, it was not possible to ensure complete patient records or data involving collapse time of each patient with EHS. Therefore, we were unable to calculate the time from patient collapse to the initiation of treatment, which is an important aspect to consider when identifying treatment outcome and prognosis. Some patients had incomplete treatment files with missing data points, which made it difficult to thoroughly analyze the treatment period itself (i.e., cooling rates within specific increments of the total treatment). However, this study was still able to show that despite these inherent limitations, the treatment protocol for this event involving quick recognition and immediate treatment via CWI results in a 100% survival rate for all patients with EHS.

The data presented in this study are the most comprehensive database to date for cases of EHS and associated treatment outcomes. This study has demonstrated the overwhelming success (100% survival rate) of using immediate (on site) CWI in the treatment of EHS and shows that this method should be used as the gold standard for EHS treatment whenever possible. In addition to the use of CWI, proper recognition and immediate cooling should be implemented when treating a case of EHS, and these factors will largely dictate the outcome of the treatment and prognosis of the patient with EHS.

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The results of the present study do not constitute endorsement by the American College of Sports Medicine.

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