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Exertional Heat Stroke Survival at the Falmouth Road Race: 180 New Cases With Expanded Analysis

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Context: A high number of exertional heat stroke (EHS) cases occur during the Falmouth Road Race.

Objectives: To extend previous analyses of EHS cases during the Falmouth Road Race by assessing or describing (1) EHS and heat exhaustion (HE) incidence rates, (2) EHS outcomes as they relate to survival, (3) the effect of the environment on these outcomes, and (4) how this influences medical provider planning and preparedness.

Design: Descriptive epidemiologic study.

Setting: Falmouth Road Race.

Patients or Other Participants: Patients with EHS or HE admitted to the medical tent.

Main Outcome Measure(s): We obtained 8 years (2012 to 2019) of Falmouth Road Race anonymous EHS and HE medical records. Meteorologic data were collected and analyzed to evaluate the effect of environmental conditions on the heat illness incidence (exertional heat illness [EHI] = EHS + HE). The EHS treatment and outcomes (ie, cooling time, survival, and discharge outcome), number of HE patients, and wet bulb globe temperature (WBGT) for each race were analyzed.

Results: A total of 180 EHS and 239 HE cases were identified. Overall incidence rates per 1000 participants were 2.07 for EHS and 2.76 for HE. The EHI incidence rate was 4.83 per 1000 participants. Of the 180 EHS cases, 100% survived, and 20% were transported to the emergency department. The WBGT was strongly correlated with the incidence of both EHS ($r^2 = 0.904$, $P = .026$) and EHI ($r^2 = 0.912$, $P = .023$).

Conclusions: This is the second-largest civilian database of EHS cases reported. When combined with the previous dataset of EHS survivors from this race, it amounts to 454 EHS cases resulting in 100% survival. The WBGT remained a strong predictor of EHS and EHI cases. These findings support 100% survival from EHS when patients over a wide range of ages and sexes are treated with cold-water immersion.

Key Words: exertional heat illness, emergency treatment, cold-water immersion, treatment outcomes

Key Points

- Cold-water immersion remains the criterion standard for exertional heat stroke care, with 100% survival from the 454 cases documented at the Falmouth Road Race.
- Wet bulb globe temperature is a very strong predictor for the incidence of both exertional heat stroke and exertional heat illness.

Exertional heat stroke (EHS) is 1 of the leading causes of sudden death in sport[1–3] and has gradually increased since the 1970s.[2] Although the risk factors and treatment resources for EHS may vary greatly across athlete populations,[4–7] survival is nearly guaranteed when the core body temperature is lowered below 38.9°C as quickly as possible.[8–10] Such aggressive cooling rates (>0.15°C/min) have only been demonstrated with cold-water immersion (CWI)[8,10–15] or similar methods (eg, tarp-assisted cooling oscillation [TACo]). Based on these data, best practices involve cooling treatment modalities that produce a cooling rate of at least 0.15°C/min.[3,14,16] Despite the overwhelming evidence supporting CWI for the survival of patients with EHS, preventable EHS deaths continue to occur in the absence of the adoption and implementation of appropriate policies and resources.[2,17,18] For this reason, it is important to continue to investigate EHS incidence, EHS survival, and factors surrounding EHS cases.

Summer road races, specifically those about 10 km (10K) in distance, tend to have a particularly high rate of EHS cases compared with other race distances.[9,19] The authors of 1 study examining three 10K road races over 19 occurrences found that EHS had the greatest incidence of all diagnoses managed by race medical tents.[9] Although the Falmouth Road Race was not included in that dataset, the majority of data on successful treatment for EHS have been published on cases at this race.[10] The Falmouth Road Race is an 11.3-km (7.1-mi) race that takes place every year in Falmouth, Massachusetts. It has become a model race for examining EHS cases given the high yearly EHS incidence rate (2.13

per 1000 finishers) coupled with a 100% survival rate as a result of CWI treatment.[10] The most recent dataset on EHS survival at Falmouth was published in 2015 and included data through 2011. The researchers assessed 18 years of data and 274 cases of EHS, making it the largest civilian EHS dataset.[10] Together, these data suggest that most summertime road race medical encounters at events around a distance of 10K are due to heat-related illnesses and, most importantly, are survivable when prompt and aggressive CWI is provided.

Environmental conditions are another important factor when anticipating patient case load of EHS at road races.[9,19–22] If warm weather is anticipated, race organizers may enact exertional heat illness (EHI) prevention strategies, such as a warm weather alert to athletes, adjusting the start time, or canceling the race altogether.[19–21] The strategy of moving the start time of the race to a time when heat stress is lower may be the least burdensome for race logistics and participants. The Falmouth Road Race traditionally had a noon start time, which was moved to 1000 hours in the 1970s[23] and then to 0900 hours in 2014; however, the effect of this change on the EHS incidence has not been evaluated.

Although pertinacity will be required to continue to save patients with EHS at these events, the EHS burden and continued ability of race personnel to successfully manage patients with EHS should be determined. Monitoring the outcomes of the Falmouth Road Race is important, as the previous publication remains the only large dataset (>100 patients) on civilian EHS survival. Ongoing evaluation of successful EHS treatment will further establish this practice not as an outlier of success but rather as the foundation and model for all mass medical events with EHS cases. Therefore, the purposes of our paper were to expand upon data from the previous Falmouth Road Race publication by (1) assessing any changes in EHS and heat exhaustion (HE) incidence rates, specifically regarding an earlier start time; (2) describing sex- or age-based differences for EHS cooling rates, initial rectal temperature (TRE), and EHS outcomes; (3) characterizing the effect of the environment on these outcomes; and (4) discussing the implications of these outcomes for medical provider planning and preparedness. We decided not to perform an in-depth analysis of sex and age on EHS outcomes due to the work of Belval et al, who comprehensively evaluated these outcomes in a larger dataset from the same race years, with the exception of 2019.[24] We hypothesized that survival rates would be similar and that incidence rates might change marginally due to the 1-hour earlier start time in recent years. Additionally, we proposed that no sex- or age-based differences would occur in cooling time or TRE and that hotter environmental conditions would be associated with increased EHS rates.

METHODS

Study Design

This was a retrospective study examining 8 years (2012 to 2019) of Falmouth Road Race medical tent records. The Falmouth Road Race is an 11.3-km (7.1-mi) running race held on the third Sunday of August in Falmouth, Massachusetts (41°52′ N, 70°67′ W), with more than 10 000 finishers each year. This study was approved by the University of Connecticut's Institutional Review Board.

Participants

We obtained anonymous medical records for the 2012 to 2019 race years. Health care providers (eg, physicians, nurses, and athletic trainers) skilled in the diagnosis and treatment of EHS identified and treated patients in the medical tent. The diagnostic criteria for EHS were a TRE >40°C with concurrent neuropsychological dysfunction (eg, confusion, combativeness, collapse), which was assessed by a qualified health care professional in the medical tent.

Environmental Conditions

Meteorologic data (eg, dry bulb temperature, dewpoint temperature, and cloud cover) were collected from the nearest available weather observing station located at Otis Air National Guard Base (41.65° N, −70.52° W), which is approximately 18.8 km from the race start. Wet bulb globe temperatures (WBGTs) were not routinely recorded during race events and were therefore computed from the meteorologic data using the Heat Stress Adviser software package[25] (version 2005; Zunis Foundation).[26] Data input into this model include air temperature, dewpoint temperature, cloud cover, and time of day. The model was developed for warm season conditions (May to September) and tested in a variety of US geographic regions, including Minnesota, New York, Oklahoma, and Texas. The WBGT estimates are accurate to ±1.1°C.[25,26] Mean WBGT values from the race start to 2 hours later were used to represent the environmental conditions experienced by the participating runners for each year.

Because the heat index was used in previously published Falmouth Road Race weather data and EHS incidence rates, we calculated the heat index with our data to determine if it was different between the 2 start times (1000 hours and 0900 hours). We used the following heat index formula:

$$
\begin{aligned}
HI = & -42.379 + 2.04901523 \times T + 10.14333127 \times RH \\
& - 0.22475541 \times T \times RH - 0.00683783 \times T^2 \\
& - 0.05481717 \times RH^2 + 0.00122874 \times T^2 \times RH \\
& + 0.00085282 \times T \times RH^2 - 0.00000199 \times T^2 \times RH^2,
\end{aligned}
$$

where T was the temperature (degrees Fahrenheit) and RH was the relative humidity (percentage). The HI was the heat index expressed as an apparent temperature in degrees Fahrenheit.

Treatment of Patients With EHS

After a diagnosis of EHS, patients were immediately immersed in a 189-L tub of water and ice (CWI). Ice was added as needed to maintain a water temperature of approximately 10°C, per written race procedures. Each tub for each patient with EHS was not monitored during treatment; however, the race medical staff leadership periodically tested the tub temperature before the start of the race. If the patients' arms and legs could not be completely immersed in the tub, towels soaked in ice water were used to cover the arms, upper legs, neck, and head. Most patients were able to fit their entire torso, hips, and lower half of their arms in the tub. Their TRE was continuously monitored. Once a patient's TRE was <38.9°C, he or she was removed from the tub to mitigate

Table 1. Descriptive Data From 454 Patients With Exertional Heat Stroke at the Falmouth Road Race, 2012–2019

Year	Initial Rectal Temperature, °C[a]	Age, y[a]	Females, No.	Males, No.	Cold-Water Immersion Treatment Time, min[a]	Home Discharges, Total No.
2012	41.5 ± 0.6	38 ± 15	6	11	16.9 ± 10.0	63% (16)
2013	41.4 ± 0.5	36 ± 14	8	7	16.3 ± 7.4	93% (15)
2014	41.4 ± 0.4	36 ± 12	9	11	14.7 ± 5.3	85% (20)
2015	41.5 ± 0.6	36 ± 12	14	28	15.3 ± 8.2	81% (42)
2016	41.0 ± 0.6	32 ± 12	7	10	10.3 ± 4.2	94% (17)
2017	41.5 ± 0.7	33 ± 15	12	15	13.5 ± 5.6	78% (27)
2018	41.0 ± 0.4	33 ± 18	2	8	11.3 ± 10.1	80% (10)
2019	41.3 ± 0.9	36 ± 14	12	19	14.2 ± 7.0	90% (31)
2012–2019 mean	41.4 ± 0.7	35 ± 14	—	—	14.4 ± 7.5	83% (178)
2012–2019 total	n = 180	n = 167	70	109	n = 159	n = 178
Before 2012[b]	41.4 ± 0.6 (n = 258)	32.1 ± 12	81	131	—	93% (n = 182)
Grand total	41.4 ± 0.6 (n = 438)	3.4 ± 13	151	240	—	88% (n = 360)

[a] Data are presented as mean ± SD except where otherwise indicated.
[b] Pre-2012 data were from DeMartini et al.[10]

hypothermic overshoot. The time from collapse to CWI treatment was not available, but general observations suggested that treatment began within minutes of collapse. The CWI treatment time was recorded, and, after cooling, all patients were kept in the medical tent for observation or sent to the hospital if indicated by supervising medical personnel (ie, when ancillary tests or interventions were required). Those who completed their recovery in the medical tent were observed until they demonstrated a normal and regulated TRE and had no signs of sequelae or complications. Patients were then discharged to the care of a responsible adult (family member, friend, etc) when deemed appropriate by the physician and were provided patient recovery information and discharge instructions to follow up with their personal physician.

Triage and Treatment for HE

All runners who presented to the medical tent with signs of EHI were triaged and assessed for neuropsychological function and initial TRE. If they did not meet the criteria for EHS or any other serious condition (eg, asthma, diabetic emergency, cardiac emergency, stroke, musculoskeletal injury), they were diagnosed with HE and provided appropriate care before release or referral, as deemed appropriate by the physician.

Statistical Analyses

Descriptive statistics for yearly EHS and HE cases, age, sex, cooling rate, and WBGT are presented as mean ± SD. We calculated a 2-tailed Pearson correlation to examine the effect of TRE and age on EHS cooling time. The strength of the correlation coefficient was defined according to Chan et al.[27] A centered polynomial regression was performed to assess the relationship between EHS and EHI incidence rates and the WBGT. We used Mann-Whitney U tests to assess the cooling rate and initial TRE by sex. Heat index differences between the start times of 1000 hours (before 2014) and 0900 hours (2014 to 2019) as well as the respective EHS incidence rates during these years were analyzed with a 1-way analysis of variance. Heat index and EHS incidence data for 14 additional years before 2012 were obtained from the DeMartini et al dataset.[20] Significance was set a priori at an α level of $P \leq .05$. Statistical analyses were performed using SPSS (version 27 for Mac; IBM Corp).

RESULTS

A total of 180 cases of EHS and 239 cases of HE were identified. Descriptive data can be found in Table 1. Incidence rates and total EHS and HE cases are reported in Table 2. Of the 180 patients with EHS, 100% survived, and 20% were

Table 2. Exertional Heat Stroke and Heat Exhaustion Cases and Incidence Rates by Year at the Falmouth Road Race

Year	Exertional Heat Stroke Cases	Heat Exhaustion Cases	Incidence Rate per 1000 Finishers			Mean Race Wet Bulb Globe Temperature, °C
			Exertional Heat Stroke	Heat Exhaustion	Total Heat Illness	
2012	17	18	1.60	1.70	3.30	24.0
2013	15	22	1.43	2.09	3.52	22.2
2014	20	16	1.81	1.45	3.25	24.1
2015	42	59	3.93	5.52	9.45	26.7
2016	17	35	1.64	3.37	5.01	24.8
2017	28	38	2.57	3.49	6.05	25.5
2018	10	9	0.90	0.81	1.72	19.8
2019	31	42	2.69	3.64	6.33	25.1
Sum or mean ± SD	180	239	2.07 ± 0.95[a]	2.76 ± 1.53[a]	4.83 ± 2.43[a]	24.0 ± 2.1[a]
Before 2012, sum or mean ± SD[a]	274	393	2.13 ± 1.62	2.97 ± 1.76	—	—
Grand total	454	632	2.11 ± 1.39	2.89 ± 1.68	—	—

[a] Pre-2012 data were from DeMartini et al,[10] and all pre-2012 exertional heat illness data were from DeMartini et al.[20]

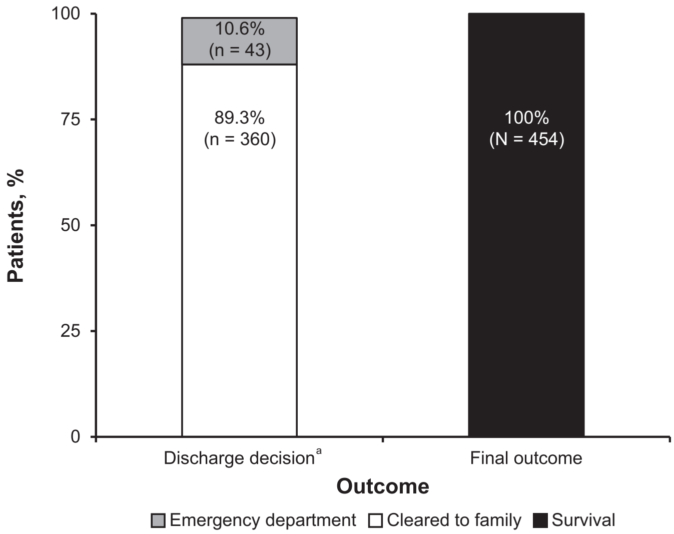

Figure 1. Final outcomes for 454 patients with exertional heat stroke at the Falmouth Road Race medical tent. *Cleared to family* indicated that a physician cleared the individual to return to family from the medical tent. Data were combined from 2012 to 2019 (n = 180) and from a previously published 18-year dataset (n = 274).[10]
[a] Discharge decisions were recorded for 403 patients.

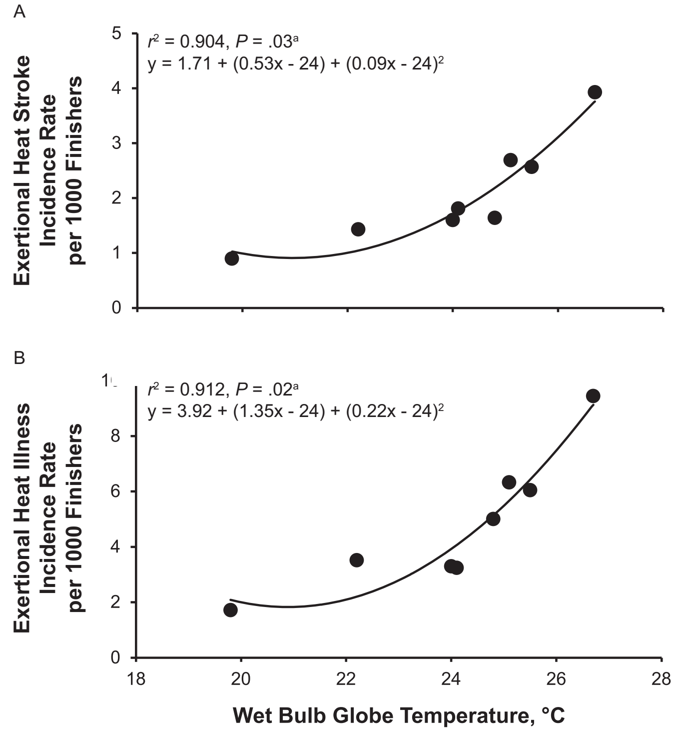

Figure 2. Correlation with exertional heat illness and wet bulb globe temperature, Falmouth Road Race, 2012–2019. (A) Correlation of exertional heat stroke cases and wet bulb globe temperature. (B) Correlation of exertional heat illness cases and wet bulb globe temperature.
[a] Indicates a difference ($P < .01$).

transported to the emergency department after cooling. When combined with our earlier data from the Falmouth Road Race, this amounted to 454 patients with EHS cases who demonstrated 100% survival; 10% were transported to the emergency department after cooling (Figure 1). Comparing the characteristics of EHS cases between sexes indicated no differences (P values $> .05$) for the initial TRE, cooling time, or discharge decision (emergency department or physician clearance to family). The TRE was significantly, although poorly, correlated with cooling time ($r^2 = 0.256$, $P < .001$). Due to this relationship, we conducted a partial correlation between age and cooling time while controlling for TRE and determined that age was not correlated with cooling time ($r^2 = 0.0003$, $P = .835$).

When WBGT was examined (range, 19.8°C to 26.7°C) in relation to the EHS and EHI incidences for each race year, a significant and very strong quadratic term was evident for both EHS ($r^2 = 0.904$, $P = .026$; Figure 2A) and EHI ($r^2 = 0.912$, $P = .023$; Figure 2B). The heat index did not differ between races held in 2013 and earlier (24.7°C ± 3.3°C, n = 14) versus those held from 2014 to 2019 (25.0°C ± 3.0°C, n = 6), despite the start time 1 hour earlier ($P = .856$). Similarly, no differences were present in the incidence rates of EHS ($P = .380$) or EHI ($P = .381$) when the incidence rates from before 2013 were compared with those between 2014 and 2019 (Table 3).

DISCUSSION

This is the second largest civilian database of EHS cases reported. When combined with our previous dataset of survivors of EHS from this same race, 100% of 454 patients with EHS survived. Therefore, a wide range of patients of different ages and sexes were successfully treated using CWI with no fatalities. Although WBGT was positively associated with increases in the incidences of EHS and EHI, the care that these individuals received still resulted in 100% survival. When analyzed as independent outcomes, initial TRE, cooling time, and discharge decision were not different between sexes. Age, when we accounted for TRE, was also not associated with cooling time.

Comparing the EHS incidence rate reported by DeMartini et al[10] (2.13 per 1000 finishers) with that of this 8-year dataset revealed a similar result (2.07 per 1000 finishers). The earlier dataset did not provide WBGT values that would allow direct comparison with the current dataset; however, weather variations could explain this small difference. In our study, the initial TRE (41.4°C ± 0.7°C) was similar to that reported by DeMartini et al (41.4°C ± 0.6°C). Last, we found that initial TRE and cooling time were not different between sexes, similar to results reported by both DeMartini et al[10] and Belval et al.[24] In addition, Belval et al[24] carried out an in-depth analysis of incidence rates for males and females at this race, which overlapped with all but 1 year of the dataset presented here; we therefore defer to Belval et al[24] for more in-depth results regarding these outcomes. Given that these studies were all performed at the same race, the similar results were expected.

Compared with previous studies of similar race circumstances (eg, similar distances, weather, and number of participants), this race continues to account for almost double the typical EHS caseload, with the most similar race being the Beach to Beacon (August; Cape Elizabeth, Maine), which had an EHS incidence rate of 1.6 per 1000 finishers between 2011 and 2017.[9] Much lower incidences have occurred at other 10K races, ranging from 0.3 to 0.6 EHS cases per 1000 finishers.[9]

Weather has an important influence on EHS at the Falmouth Road Race. Prior Falmouth Road Race data have displayed

Table 3. **Exertional Heat Stroke Cases Before and After Implementation of a Start Time 1 Hour Earlier at the Falmouth Road Race**

Start Time, Years Included	Exertional Heat Stroke Cases	Exertional Heat Illness Cases	Incidence Rate per 1000 Finishers		Heat Index, °C
			Exertional Heat Stroke	Exertional Heat Illness	
1000 hours, before 2014 (n = 14)[a]	306	465	2.04 ± 1.51	3.03 ± 1.62	24.7 ± 3.3
0900 hours, 2014 to 2019 (n = 6)	148	347	2.25 ± 1.05	5.30 ± 2.68	25.0 ± 3.0

[a] Data before 2012 were added and compiled from DeMartini et al.[10]

Table 4. **Falmouth Road Race Exertional Heat Stroke Equipment Needs Estimated by Race Day Wet Bulb Globe Temperature[a]**

Equipment	Minimum Number (Assuming 17°C–19°C WBGT)	Number to Add for Every Additional 1°C WBGT Increase >19°C	Projected Maximum (Number Needed Assuming 33°C WBGT)
Immersion tubs	5	4	60
Water, L	946.4	757.1	11 356.2
Ice, 13.5-kg bags	15	12	180
Disposable rectal thermometer probes	5	4	60

Abbreviation: WBGT, wet bulb globe temperature.
[a] The minimum and maximum numbers do not provide any "extra" supplies for additional cases.

moderately strong relationships between r^2 values in both the heat index ($r^2 = 0.74$)[20] and WBGT ($r^2 = 0.61$)[21] and the EHS incidence. We also showed a significant and very strong rise in EHS incidence rates with increases in WBGT ($r^2 = 0.904$). Other races with EHS cases at 10K events have reflected much smaller associations with WBGT ($r^2 = 0.13$). Unique to this study, we found that moving the race 1 hour earlier did not affect the EHS or EHI incidence rate (Table 3). However, given the strong relationship between WBGT and the EHS incidence, it seems likely that this relationship depends more on weather patterns than the time of day.

Organizers of summer road races should be prepared to use CWI for patients with EHS to ensure survival and mitigate the complications associated with delayed care. The Falmouth Road Race in particular has 4 on-course medical tents. In total, these supply more than 30 CWI tubs, more than 100 treatment cots, and water in each tent. Ice trucks deliver ice to each tent (and 1 truck stays on site at the finish line) to prepare for these patients. Such ratios (ie, 1 to 2 tubs per patient with EHS, on average) can be a helpful guide for race organizers preparing for similar warm-weather road races. By using the WBGT-based EHS incidence projection at the Falmouth Road Race, we can effectively provide a realistic understanding of the EHS caseload. The coolest race year (19.8°C WBGT) had an incidence of about 1 EHS case per 1000 participants (about 10 to 12 EHS cases) versus the hottest race year since 2012 (26.7°C WBGT), which would have a projected 3.2 EHS cases per 1000 participants (about 32 to 36.4 total EHS cases; Table 4). Road race medical organizers can use a similar approach to help anticipate the medical supplies needed to address unusual or unanticipated changes in race day WBGT. Ideally, these would be specific to the EHS and EHI cases seen at the race with various WBGT values.

CONCLUSIONS

Overall, these data continue to support 100% survival when CWI is quickly and effectively applied to patients with EHS participating in road races. When combined with previous data from this race,[10] 26 years of race data and 454 survivors of EHS were documented. When comparing the findings by sex, we did not identify differences in initial TREs, cooling times, or discharge decisions. Increases in both the EHS incidence and overall volume of HE cases occurred with increases in environmental conditions, most prominently when >24°C. These race-specific considerations and plans should be used to treat these individuals. Other warm-weather road race medical teams should consider a similar model to address potential EHS cases and provide the best possible chance for 100% survival.

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