Letter to the Editor

Determinants of Exertional Heat Stroke: Are Children and Youth Indeed More Vulnerable?

Readers should keep in mind that the in-production articles posted in this section may undergo changes in the content and presentation before they appear in forthcoming issues. We recommend regular visits to the site to ensure access to the most current version of the article. Please contact the JAT office (jat@slu.edu) with any questions.
Dear Editor:

In their recent paper, “Age- and Sex-Based Differences in Exertional Heat Stroke Incidence in a 7-Mile Road Race,” Belval et al. aimed to evaluate age, sex, and environmental conditions as determinants of exertional heat stroke (EHS). More than 155,000 records over a 16-year recurrence of the same race, run over the same course, is a remarkable database, and the authors ought to be commended for pursuing and analyzing it. They found males and youth to be more at risk than females and adults. The findings appear to be sound statistically and methodologically, but the conveyed implications may be misleading.

The authors’ recommendation that medical personnel should be prepared to deal with EHS cases is well justified. However, EHS is preventable and it is incumbent upon researchers and authors to be cognizant of and inform their readers about the risks and causes of EHS, so as to not neglect vulnerabilities, on the one hand, or unnecessarily hinder those who do not need extra protection, on the other hand. Let me present a few points for consideration.

Excluding pathologic conditions, susceptibility to EHS in an endurance event, such as a running race, depends on environmental conditions, age, and sex—factors the authors included in their analysis—but also on the individual’s level of fitness, heat acclimatization, exertional intensity, and adiposity, all of which determine the exertional level.

Acclimatization, effort, and adiposity levels are impossible to assess on a large-scale or in retrospect, but a good if imperfect proxy of exertion is actual performance: running time in this case. Importantly, aside from fitness per se, running time reflects the rate of heat production, which is central to EHS development. Although the authors were aware of this factor in reporting running times for the EHS-afflicted runners (Table 2), they did not provide references to mean
running times of those runners’ respective sex and age groups. More crucially, running times were not included as part of the study’s factor analysis.

Available online race statistics (https://falmouthroadrace.com/results/previous-falmouth-results/) revealed that the unweighted mean time of the boys’ 10th-place finishers in the <14 years category from 2014 through 2018 was approximately 52 minutes, 46 seconds. Given that the study’s reported 2003 through 2018 mean running time of the EHS-affected boys was 51.77 minutes, it seems safe to say that EHS in the <14-year-old boys was most prevalent among the top finishers who exerted themselves more than most other racers in that category. Although such a relationship cannot readily be discerned from the other groups’ data, this does not take away from the fact that running time reflects the rate of heat production per body mass. Everything else being equal, the faster one runs, the greater are the chances of developing EHS. Clearly, nobody develops EHS by running too slowly! Thus, running time is a major EHS factor that deserves analysis along with the other quantifiable variables.

The question of whether boys, and males in general, are more susceptible to EHS than females, is a sticky one. Whether or not exertion develops depends very much on competitiveness, which translates to elevated effort and rate of heat production beyond what the individual may be physiologically prepared for. Men and boys are typically more competitive than girls and women2 and this reason alone, rather than any innate physiological difference, could explain the males’ reported approximately 40% higher EHS risk. Moreover, children are notoriously bad at gauging and pacing their efforts, which may well result in early excessive speed and heat accumulation that could precipitate premature EHS.

So, in practice, the EHS prevalence among boys and youth may indeed be higher in some or all running races held in warm or hot weather, but inferring greater EHS susceptibility of
children and youth contradicts current understanding and the best available data. Contrary to what the authors claimed, our cited review\textsuperscript{3} did NOT propose that “adolescents are... at a greater risk for heat illness due to an altered body mass-to-surface area ratio.” Rather, children’s greater surface-area-to-mass ratio makes their predominant thermoregulatory strategy more reliant on dry heat dissipation than on the sweating that is more dominant in adults. It does not, however, compromise their heat tolerance, in general, nor their heat-stressed exercise tolerance, as long as ambient temperatures do not approach skin temperature. It is only under high ambient temperatures that dry heat dissipation can be seriously compromised, possibly rendering children more vulnerable. As ambient temperature data were not made available, one must rely on the provided composite wet bulb globe temperature index. The latter never exceeded 27°C, and it can thus be reasonably deduced that ambient temperatures hardly if ever exceeded 30°C, well within children’s uncompromised thermoregulatory zone.

Due to their primary reliance on dry heat dissipation, children may be even less dehydration prone than adults. Also, a 7-mile road running race is of borderline duration with respect to the need for in-race hydration. These 2 facts make it unlikely that dehydration was a major factor in the observed incidence of EHS among young runners. It is entirely possible, however, that some of the runners of any age with EHS started the race in a less-than-optimal hydration status, thus making them prone to dehydration and EHS. This is an unaccountable confounding factor that could possibly explain some EHS cases, even among relatively slow runners. It ought to be stressed that slow running may not necessarily reflect a low level of effort or relative intensity but rather simply low fitness, a risk factor in its own right.

Indeed, if my views and review are not convincing enough, then the Figure from Berko et al\textsuperscript{4} ought to do that. Although it does not distinguish between exercise- and non–exercise-related
incidents, it clearly shows that between 2006 and 2010, for example, the incidence of both heat- and cold-induced deaths in the US was lowest in the aged 5–14 years group and second lowest in those aged 15 to 24 years. What is a better way to demonstrate children’s relative heat invulnerability?

Thus, while claiming that “only younger age significantly accounted for an increased risk of EHS” may be statistically correct for the Falmouth 7-mile road race, it is misleading in placing the “blame” on age and sex. It may well be unrealistic to expect race organizers to assume full responsibility for prevention, but among the organizers and the community, the educational and the athletic establishments, it might be possible to do some or all of the following, which could benefit everybody, not only the groups that were singled out.

- Encourage proper training and preparation in the months leading to the race.
- Recommend that some training be done in warm or even hot weather to ensure heat acclimatization.
- Educate children and youth about the importance of proper pacing, as a means of enhancing ultimate performance and minimizing the EHS risk. This could and should be part of the preparatory training, perhaps as a component of physical education.
- Encourage and make available adequate prerace hydration (cool water should suffice).
References

1. Belval LN, Giersch GEW, Adams WM, et al. Age- and sex-based differences in exertional heat stroke incidence in a 7-mile road race. *J Athl Train*. 2020;55(12):1224–1229. doi:10.4085/1062-6050-539-19

2. Deaner RO. More males run fast: a stable sex difference in competitiveness in US distance runners. *Evol Hum Behav*. 2006;27(1):63–84. doi:10.1016/j.evolhumbehav.2005.04.005

3. Falk B, Dotan R. Children’s thermoregulation during exercise in the heat: a revisit. *Appl Physiol Nutr Metab*. 2008;33(2):420–427. doi:10.1139/H07-185

4. Berko J, Ingram DD, Saha S, Parker JD. Deaths attributed to heat, cold, and other weather events in the United States, 2006–2010. *Natl Health Stat Rep*. 2014;76:1–15.
Figure. Crude death rates for weather-related mortality, by age: United States, 2006–2010.
Raffy Dotan, MSc

Department of Kinesiology

Faculty of Applied Health Sciences

Brock University

St Catherines, ON

Canada
Heat-related, cold-related, and other weather-related death rates varied by age (Figure 1 and Table 2). The pattern across age groups was similar for heat-related and cold-related mortality: progressive moderate increases in the death rates between ages 15 and 74, a substantial increase in the death rate for persons aged 75–84, and an even larger increase in the rate for persons aged 85 and over. The heat-related death rate for infants was higher than the cold-related death rate (4.2 compared with 1.0 deaths per million), but among persons aged 5 years and over, cold-related death rates were consistently higher than heat-related death rates, and the differentials in the rates across the age groups were larger. The heat-related death rate was lowest for children aged 5–14 years (0.1 deaths per million) and increased from 0.5 deaths per million among persons aged 15–24 to 4.5 deaths per million among persons aged 65–74. The rates for persons aged 75–84 (7.5 deaths per million) and persons aged 85 and over (12.8 deaths per million) were substantially higher than those for younger persons. The heat-related death rate for infants (4.2 deaths) was higher than the rates for persons aged 1–44 and as high as the rates for persons aged 45–64.

The cold-related death rate for infants was 1.0 deaths per million, which was higher than the rate for children aged 5–14 but lower than the rates for persons aged 25 and over. Cold-related death rates were lowest for children aged 5–14 (0.2 deaths per million) and increased progressively with age, as was the case for heat-related mortality, with rates increasing from 1.3 to 7.8 deaths per million among persons aged 15–74. The cold-related death rates for persons aged 75 and over were substantially higher than the rates for younger persons: 15.5 deaths per million among persons aged 75–84 and 39.6 deaths per million among persons aged 85 and over.

The rate of deaths attributed to floods, storms, and lightning was low in all age groups (ranging from 0.2 deaths per million for children aged 14 years and under to 1.0 for persons aged 85 and over). Generally, differences among the age groups were not statistically significant for flood-storm-lightning-related mortality.

During 2006–2010, about 68% of the weather-related deaths were among males (Table 3). The age-adjusted heat-related and cold-related death rates for males were more than 2.5 times as high as those for females (3.1 compared with 1.2 deaths per million for heat-related mortality and 6.3 compared with 2.4 for cold-related mortality). Males were twice as likely as females to die due to floods, storms, or lightning (0.6 compared with 0.3 deaths per million).

Non-Hispanic black persons had higher rates of heat-related and cold-related mortality than other race and ethnicity groups during 2006–2010 (Table 3). For heat-related mortality, the rate for non-Hispanic black persons was about 2.5 times that for non-Hispanic white persons and about 2 times as high as that for Hispanic persons. The age-adjusted cold-related death rate for non-Hispanic black persons was 5.8 deaths per million compared with 4.1 deaths per million.

Figure 1. Crude death rates for weather-related mortality, by age: United States, 2006–2010

1Deaths attributed to exposure to excessive natural cold (X31) (underlying or contributing cause of death or both), to hypothermia (T68) (contributing cause of death), or to both, according to the International Classification of Diseases, 10th Revision.
2Deaths attributed to exposure to excessive natural heat (X30) (underlying or contributing cause of death or both), to heat stroke or sunstroke (T67) (contributing cause of death), or to both, according to the International Classification of Diseases, 10th Revision.
3Deaths attributed to floods (X38), cataclysmic storms (X37), or lightning (X33) (underlying or contributing cause of death or both), according to the International Classification of Diseases, 10th Revision.

SOURCE: CDC/NCHS, National Vital Statistics System, 2006–2010.
Dear Editor,

We appreciate the opportunity to respond to the letter about our investigation of age, sex, environmental conditions, and the incidence of exertional heat stroke (EHS) in a warm-weather road race. The letter author raises some points that allow us to further expand upon our findings and, we hope, provide adequate context for their concerns.

Overall, in examining the implications of this investigation, we appear to diverge from the author of the letter on a key point. He argues that EHS is preventable. Although every case of EHS is theoretically preventable, the large numbers of people with a variety of individual risk factors exercising in warm environments make total prevention nearly impossible. In addition to running road races, large-scale events involving exercise, such as military basic training, are subject to similar concerns regarding exertional heat illnesses despite comprehensive prevention efforts. However, I reiterate that data from this very race indicated that mortality from EHS did appear to be preventable with appropriate treatment.

The purpose of this investigation was to examine the factors that influence the incidence of EHS on a population level. Furthermore, we sought to identify the factors that medical teams and race organizers might be able to consider before the road race to help determine the staff and supplies needed to appropriately treat patients with EHS. In our discussion, we fully acknowledged that EHS risk is multifactorial and consists of both intrinsic and extrinsic factors. However, the individual factors of the participants in running road races cited by the letter author (fitness, heat acclimatization, adiposity, and
exertional intensity) are unknown and would likely require advanced laboratory
techniques to ascertain. Even if these data were available for the cases presented, the
utility of these analyses for on-site medical providers is limited. The mechanistic insights
the author of the letter tried to glean from the presented data are beyond the scope of
these data.
Several times, the letter author referenced our findings, saying that males and youth
were found to be at a higher risk of EHS. Throughout the paper, we referred to the
results as applying to “younger runners,” not “youth,” and further clarified in the
conclusion that these results primarily applied to runners aged 19 to 39 years. We made
this distinction for many of the reasons the author of the letter stated, including the fact
that the physiological and behavioral circumstances of individuals under the age of 18
participating in this race were unique.

The letter author denoted several factors that may play a role in children having altered
susceptibility to EHS. He correctly indicated that an altered body mass-to-surface area
ratio did not solely explain the altered risk in youth individuals, and it is clear from his
review that a description of the nuances of this risk extends beyond what is included in
our manuscript. Runners under the age of 14 accounted for only 2.4% of race
participants and 2.6% of patients with EHS. However, we would caution the author to
avoid comparing EHS- and heat-related deaths (which include nonexertional cases); the
mechanisms and causes of these conditions are clearly disparate.
Finally, the author of this letter highlighted the claim “only younger age accounted for an
increased incidence of EHS.” Yet I would like to stress that this statement was taken out
of context: the other part of that sentence reads, “However, when sex was considered
with age and WBGT [wet bulb globe temperature]….” We did not characterize age as the sole risk factor for EHS, but rather our data supported that of those variables we could study, age did statistically explain the greatest variance in EHS incidence.

I conclude by emphasizing that our findings were epidemiologic in nature. Many factors influence an individual’s susceptibility to EHS; by examining the patterns of EHS incidence in events such as this, we can observe trends that either allow researchers to study these mechanisms in controlled environments or establish reference incidences for medical providers. I agree with the letter author’s recommendations to increase community collaboration and minimize the risk globally for all runners using the precautions listed.
References

1. Belval LN, Giersch GEW, Adams WM, et al. Age- and sex-based differences in exertional heat stroke incidence in a 7-mile road race. *J Athl Train.* 2020;55(12):1224–1229. doi:10.4085/1062-6050-539-19

2. Update: heat illness, active component, US Armed Forces, 2019. *MSMR.* 2020;27(4):4–9.

3. Demartini JK, Casa DJ, Stearns R, et al. Effectiveness of cold water immersion in the treatment of exertional heat stroke at the Falmouth Road Race. *Med Sci Sports Exerc.* 2015;47(2):240–245. doi: 10.1249/MSS.0000000000000409

4. Casa DJ, DeMartini JK, Bergeron MF, et al. National Athletic Trainers’ Association position statement: exertional heat illnesses. *J Athl Train.* 2015;50(9):986–1000. doi: 10.4085/1062-6050-50.9.07
Luke N. Belval, PhD, ATC, CSCS
Thermal and Vascular Physiology Lab
Institute for Exercise and Environmental Medicine
University of Texas Southwestern Medical Center
Texas Health Presbyterian Hospital Dallas