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

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[1] 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 results 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.

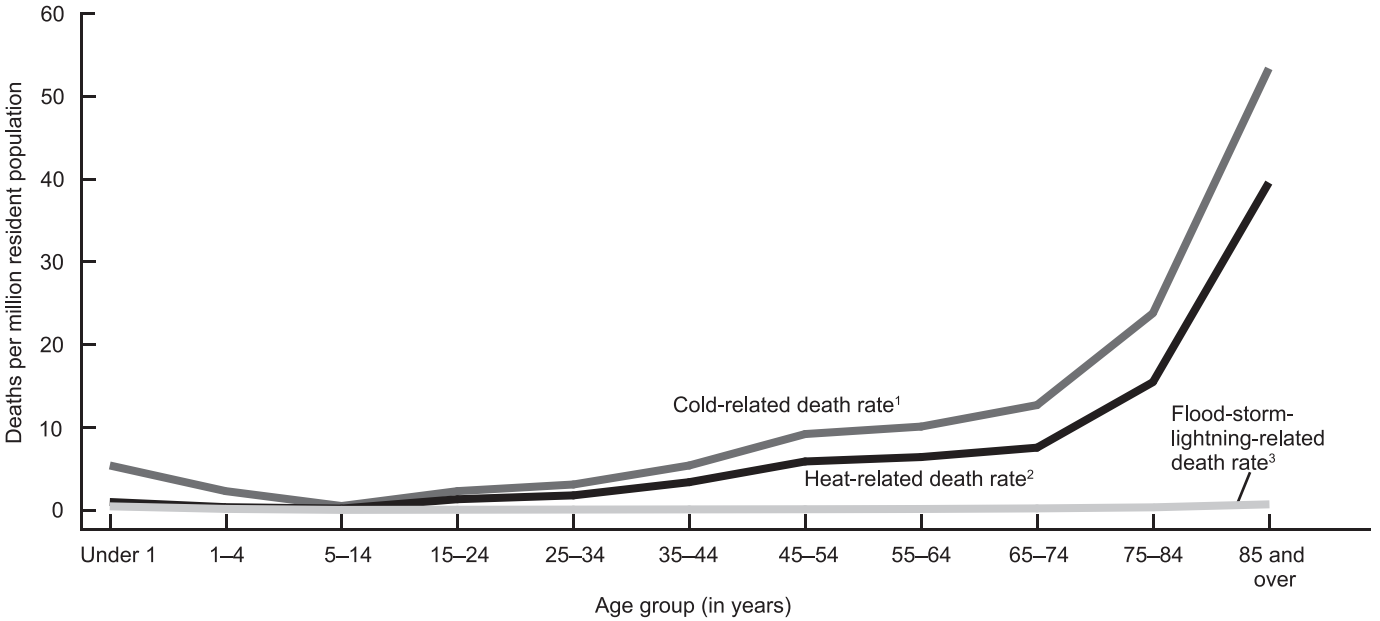
Acclimatization, effort, and adiposity levels are impossible to assess on a large scale or in retrospect, but a good, if imperfect, proxy of exertion is actual performance: running time in this case. Importantly, aside from fitness per se, running time reflects the rate of heat production, which is central 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 the 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 women,[2] 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 excessive early 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[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 sweating, which 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



[1]Deaths 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*.
[2]Deaths 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*.
[3]Deaths 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.

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

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 EHS-afflicted runners, of any age, 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[4] ought to be. Although it does not distinguish between exercise- and nonexercise-related incidents, it clearly shows that, between 2006 and 2010, for example, the incidence of both heat- and cold-induced deaths in the United States was lowest in those aged 5–14 years and second lowest in those aged 15–24 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 with cooperation of the organizers and the community, the educational and the athletic establishments, it may be possible to do some or all 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).

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