Risk Factors for Illness-related Medical Encounters during Cycling: A Study in 102,251 Race Starters—SAFER XI

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ABSTRACT

Purpose: There are limited data on risk factors associated with illness-related medical encounters (illME) in cycling events. The aim of this study was to determine risk factors associated with illME in mass community-based endurance cycling events.

Methods: This is a retrospective cross-sectional study in the Cape Town Cycle Tour (109 km), South Africa, with 102,251 race starters. All medical encounters for 3 yr were recorded by race medical doctors and nurses. illME were grouped into common illnesses by final diagnosis. A Poisson regression model was used to determine whether specific risk factors (age, sex, cycling speed, and average individual cyclist wet-bulb globe temperature [aiWBGT]) are associated with illME, serious and life-threatening or death ME, and specific common illME.

Results: Independent risk factors associated with all illME during an endurance cycling event were slow cycling speed ($P = 0.009$) and higher aiWBGT ($P < 0.001$). Risk factors associated with serious and life-threatening or death ME were older age ($P = 0.007$) and slower cycling speed ($P = 0.016$). Risk factors associated with specific common illME were fluid and electrolyte disorders (females, older age, and higher aiWBGT) and cardiovascular illness (older age).

Conclusion: Females, older age, slower cycling speed, and higher aiWBGT were associated with illME in endurance cycling. These data could be used to design and implement future prevention programs for illME in mass community-based endurance cycling events.

Keywords: CYCLING, ENDURANCE SPORTS, ILLNESS, RISK FACTORS, EPIDEMIOLOGY, SAFER STUDY

The benefits of regular moderate- to high-intensity physical activity are well known, especially in the prevention and management of noncommunicable diseases (1–5). With the increased knowledge base of physical activity benefits, the participation rates in mass community-based events, such as distance running and cycling, has increased (6). However, these prolonged moderate- or high-intensity exercise mass community-based events have an increased risk of medical encounters (ME) (7,8).

Recording of ME in such events has now been standardized (9), with a shift to not only report sudden cardiac arrests and deaths (7,8) but also acute injury-related and illness-related medical encounters (illME). In cycling, research has predominantly focused on acute injuries during events, with only a few studies examining the illME. One study has reported the incidence of all adverse events (a participant requiring medical attention and not completing the event) during a single-day cycle race at 11.88 per 1000 race starters, but this included acute injuries (10). In only one study from a multiday cycling event, the most common illME were heat-related illnesses comprising (17%–35% of all ME reported), followed by gastrointestinal (25%), respiratory complaints (4%–25%), and cardiovascular (15%) (11–13). In addition to limited data on the incidence of illME in cycling, factors associated with illME have not yet been thoroughly investigated. In a few studies where risk factors have been investigated, the definitions and types of illME (other than heat illness) have not been consistent (10,14). Data regarding illME and their respective risk factors are clinically important, as this is the first step to design and implement specific illness prevention programs and better prepare medical teams and facilities on race day. These data are also important to ensure safe events and to continue the promotion of physical activity in a safe environment.

We recently reported the incidence of illME, cardiac arrests, and deaths in 102,251 race starters participating in a 109-km community-based mass participation cycling event (15). The incidence rate (IR) of all illME was 2.1 per 1000 starters, and the most common systems affected were fluid/electrolytes, cardiovascular, and respiratory (16). We now wish to explore selected independent risk factors that may be associated with illME during this mass community-based participation endurance cycling event (Cape Town Cycle Tour). We also wanted to identify the risk factors associated with (a) serious life-threatening illME and (b) specific common illME in different organ systems.

METHODS

Study Design

This is a cross-sectional study with a retrospective analysis of data collected over 3 yr (2012–2014).

Participants and Demographics

This study forms part of a series of studies known as the Strategies to Reduce Adverse Medical Events for the Exerciser (SAFER) studies (17). More specifically, this study is a component of the retrospective analysis of data collected on all race starters during the Cape Town Cycle Tour from 2012 to 2014. The details of the study methodology have previously been fully described (16). Ethical clearance was obtained from the Research Ethics Committee of the University of Pretoria (REC R430/2015).

In summary, the Cape Town Cycle Tour is a single-day cycling event held annually in Cape Town, attracting approximately 30,000 cyclists (both recreational and elite). This 109-km race uses the same route every year (in the years studied, the route remained the same; however, in the event of high-risk conditions in other years, the route has been changed), requires no qualifying time or minimum entry requirements, and race entrants are from >13 yr to older (there is no upper age limit). Owing to the large number of participants, the race start is staggered over 4 h on race day, from 6:00 to 10:00 am. Start times are based on seeding categories of riders, using their previous participation/performance in similar cycling events.

During the study period, a total of 128,350 cyclists registered for the races, 102,251 cyclists started the races (80,354 males, 21,897 females; race starters = 79.7% of registrations), and only the starters were included in this study (see Table, Supplemental Digital Content 1, Demographics of all race starters (by sex, age group and year) included in the study (n; %), http://links.lww.com/MSS/C103). Of the starters, 97,335 (95.2% of starters) finished the race (77,074 males—96% of starters; 20,261 females—92.5% of starters)).

ME Data Collection

We previously reported the details of the medical data collection procedure and specific definitions (9,16), and these are in accordance with the 2019 international consensus statement on data collection in mass community-based events (9). The Cape Town Cycle Tour is a well-established event with an extensive medical and technical support team. On race day, ME and withdrawals are swiftly and safely attended to by trained professionals, and all these encounters are recorded by race officials. Therefore, each illME was accurately recorded by attending physicians and nurses on each race day during the 3-yr study period, using a standardized format. Diagnoses were made clinically in most instances, except when point-of-care testing was available to diagnose specific conditions such as hyponatremia. Only illME of moderate and serious life-threatening severity (or death) were reported (9). illME were subclassified by severity (moderate, serious life-threatening, or death ME) and main organ system affected (9) as follows: fluid and electrolyte disorders, cardiovascular system, respiratory disease, central nervous system, heat illness, gastrointestinal system, dermatological system, endocrine/metabolic system, and genitourinary system. For the purposes of this study, only risk factors associated with the following three most common organ system–specific illME are explored: fluid and electrolyte disorders, cardiovascular system, and respiratory disease.

Environmental conditions on race days for each year

On race day, hourly data regarding the environmental conditions were collected between 6:00 am and 5:00 pm. These data were collected from five automated weather stations of the South African Weather Services along the race route. We calculated an average individual wet-bulb globe temperature (aiWBGT) exposure value (as an individual cyclist-specific metric of environmental condition exposure) for each of the 102,251 race starters, using the individual cyclist starting and finishing time, and the hourly data we obtained at each of the five weather stations on the route. The details of the calculation of the aiWBGT are available (see Table and text in Supplemental Digital Content 2, Calculation of average individual wet-bulb globe temperature (aiWBGT), http://links.lww.com/MSS/C104).

Incidence of illME

We previously reported the incidence of illME per 1000 race starters (as per the consensus statement) (9). These incidences were also reported in subgroups of cyclists by organ system and final diagnosis. We now report the incidences by sex, age-group, cycling speed, and aiWBGT.

Patient and public involvement (PPI)

We did not directly include PPI in this study, but the database used in the study was developed with PPI and is updated by a group that includes patient advisory representatives, including the race organizer and medical director.

Primary Outcome

The primary outcome was to identify independent risk factors that were associated with all illME during the Cape Town Cycle Tour over the 3-yr study period (using demographic data from the starter database, and race day factors). Secondary outcomes were to identify the independent risk factors associated with (a) serious life-threatening or death ME and (b) specific common illME by organ systems as follows: fluid and electrolyte, cardiovascular, and respiratory.

Statistical Analysis of Data

All cyclist entry data were entered into a database and analyzed using SAS statistical software (version 9.4; SAS Institute Inc., Cary, NC). The binary dependent variable indicated whether the cyclist had an illME or not. Because some of the modeling encountered convergence problems, a Poisson regression with robust SE were used with the specified independent variables of interest. As the same cyclist could have entered and started the race up to three times in this period, the correlated structure of the data was accounted for by specifying an exchangeable correlation structure type. IR was calculated for illME (% and 95% confidence interval [CI]) using multiple regression modeling adjusting for sex, age-group, cycling speed, and aiWBGT for all illME, and univariate analysis for specific illME. The statistical significance level was 5%, unless otherwise specified.

RESULTS

Age, sex, cycling speed, and individual environmental exposure as risk factors associated with all illME

The overall IR of all illME was 2.1 (1.8–2.4). The IR values of all illME for sex, age-group, cycling speed, and aiWBGT using a multiple regression model are depicted in Table 1 (resulting in independent risk factors).

TABLE 1. The IR (per 1000 cyclists starting the race: 95% CI) of all illME in the 3-yr study period.

	Variable	Category	n	IR (95% CI)	IR (95% CI)	P*
All illME	Sex	Female	62	2.4 (1.8–3.3)	1.3 (1.0–1.9)	0.094
		Male	153	1.8 (1.5–2.2)		
	Age-group (yr)	≤50	157	1.9 (1.5–2.3)		0.207
		>50	58	2.3 (1.7–3.1)	1.2 (0.9–1.7)	
	Cycling speed (km·h−1)a	20	202	2.2 (1.8–2.7)	1-unit increase, 1.0 (0.9–1.0)	0.009
		25		1.7 (1.3–2.1)		
	aiWBGTb	13.8	205	2.0 (1.6–2.5)	2-unit increase, 1.3 (1.1–1.5)	<0.001
		14.4		2.2 (1.8–2.7)		
		17.5		3.3 (2.7–4.0)		

n, number of participants with illness.

*P value for the variable in the model.

aContinuous variable, represents two specific points.

bContinuous variable, represents the 1st quartile, the median, and the 3rd quartile. Numbers of participants are therefore not available.

Significant risk factors associated with all illME were slower cycling speed (P = 0.009) and increased aiWBGT (P < 0.001).

Age, sex, cycling speed, and individual environmental exposure as risk factors associated with specific illME

The overall IR values per 1000 starters were 0.3 (0.2–0.4) for serious life-threatening illness or deaths, 0.6 (0.5–0.8) for fluid/electrolyte, 0.5 (0.3–0.6) for cardiovascular, and 0.2 (0.2–0.4) for respiratory illness. Risk factors associated with specific illME using a univariate analysis are presented in Table 2.

For serious life-threatening or death ME, older age ($P = 0.007$) and slower cycling speed ($P = 0.016$) were associated with a significantly higher risk. Females ($P = 0.034$), slower cycling speed ($P = 0.0286$), and increased aiWBGT ($P < 0.001$) were associated with an increased risk of fluid/electrolyte illME. Older age ($P = 0.001$) was associated with an increased risk of cardiovascular illME.

Environmental (aiWBGT) as a specific risk factor associated with illME

The relationship between IR of all illME and aiWBGT is depicted in Figure 1.

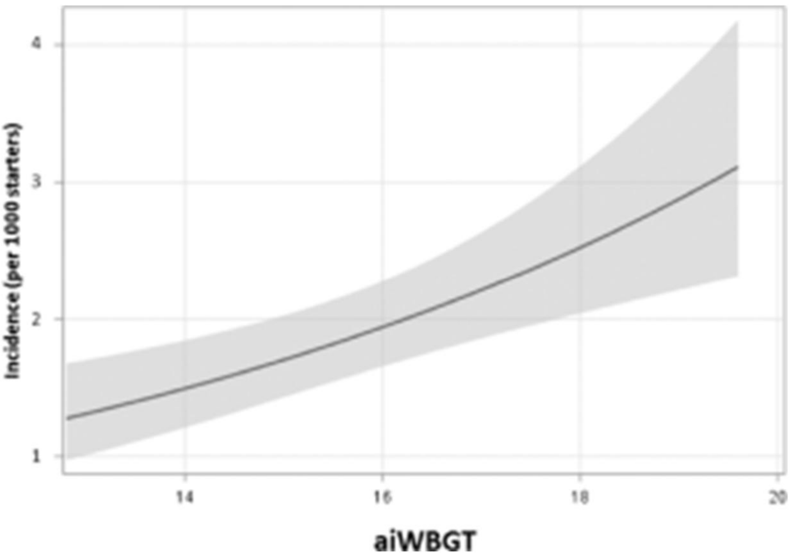

FIGURE 1. all illME incidence for aiWBGT ($P = 0.0005$). Model for participants 40.88 yr old (average age), cycling at 23.79 km·h−1 (average speed). Wide CI values are indicative of a small sample size at that aiWBGT.

For aiWBGT, a 2-unit increase was associated with a significantly higher risk of all illME (IR = 1.3, 95% CI = 1.1–1.5).The relationship between IR for serious life-threatening illness or death ME, fluid/electrolyte illME, cardiovascular illME, and respiratory illME are represented in Figure 2A–D, respectively.

TABLE 2. The IR (per 1000 cyclists starting the race: 95% CI) of serious life-threatening illME or death ME, fluid and electrolyte illME, cardiovascular illME, and respiratory illME (three main organ systems) in the 3-yr study period.

	Variable	Category	n	IR (95% CI)	IR (95% CI)	P*
Serious life-threatening illness or death	Sex	Female	7	0.3 (0.2–0.7)	1.2 (0.5–2.9)	0.662
		Male	21	0.3 (0.2–0.4)		
	Age-groups (yr)	≤50	13	0.2 (0.1–0.3)		0.007
		>50	15	0.6 (0.4–1.0)	3.6 (1.7–7.7)	
	Cycling speed (km·h−1)a	20	28	0.4 (0.2–0.5)	1-unit increase, 0.9 (0.8–1.0)	0.016
		25		0.2 (0.1–0.4)		
	aiWBGTa	13.8	27	0.2 (0.1–0.4)	2-unit increase, 1.3 (0.9–1.7)	0.189
		14.4		0.2 (0.1–0.4)		
		17.5		0.3 (0.2–0.5)		
Fluid/electrolyte	Sex	Female	21	1.0 (0.6–1.5)	2.0 (1.2–3.4)	0.034
		Male	39	0.5 (0.4–0.7)		
	Age-groups (yr)	≤50	50	0.6 (0.5–0.8)		0.132
		>50	10	0.4 (0.2–0.8)	0.6 (0.3–1.2)	
	Cycling speed (km·h−1)a	20	56	0.7 (0.5–0.9)	1-unit increase, 0.9 (0.9–1.0)	0.029
		25		0.5 (0.3–0.7)		

	aiWBGTa	13.8	59	0.3 (0.2–0.5)	2-unit increase, 1.8 (1.4–2.3)	<0.001
		14.4		0.4 (0.2–0.5)		
		17.5		0.9 (0.7–1.2)		
Cardiovascular	Sex	Female	8	0.4 (0.2–0.7)	0.8 (0.4–1.6)	0.426
		Male	39	0.5 (0.4–0.7)		
	Age-groups (yr)	≤50	23	0.3 (0.2–0.4)		0.001
		>50	24	1.0 (0.7–1.5)	3.3 (1.9–5.8)	
	Cycling speed (km·h–1)a	20	45	0.5 (0.4–0.7)	1-unit increase, 1.0 (0.9–1.0)	0.182
		25		0.4 (0.3–0.6)		
	aiWBGTa	13.8	45	0.4 (0.2–0.6)	2-unit increase, 1.2 (0.9–1.6)	0.174
		14.4		0.4 (0.3–0.6)		
		17.5		0.6 (0.4–0.8)		
Respiratory	Sex	Female	10	0.5 (0.2–0.8)	2.4 (1.1–5.4)	0.076
		Male	15	0.2 (0.1–0.3)		
	Age-groups (yr)	≤50	19	0.3 (0.2–0.4)		0.082
		>50	3	0.1 (0.0–0.4)	0.4 (0.1–1.4)	
	Cycling speed (km·h–1)b	20	23	0.3 (0.2–0.4)	1-unit increase, 1.0 (0.9–1.1)	0.439

		25		0.2 (0.1–0.3)		
	aiWBGTa	13.8	25	0.3 (0.2–0.4)	2-unit increase, 1.0 (0.6–1.5)	0.932
		14.4		0.3 (0.2–0.4)		
		17.5		0.3 (0.1–0.5)		

n, number of participants with illness.

*P value for the variable in the model.

aContinuous variable, represents the 1st quartile, the median, and the 3rd quartile. Numbers of participants are therefore not available.

bContinuous variable, represents two specific points.

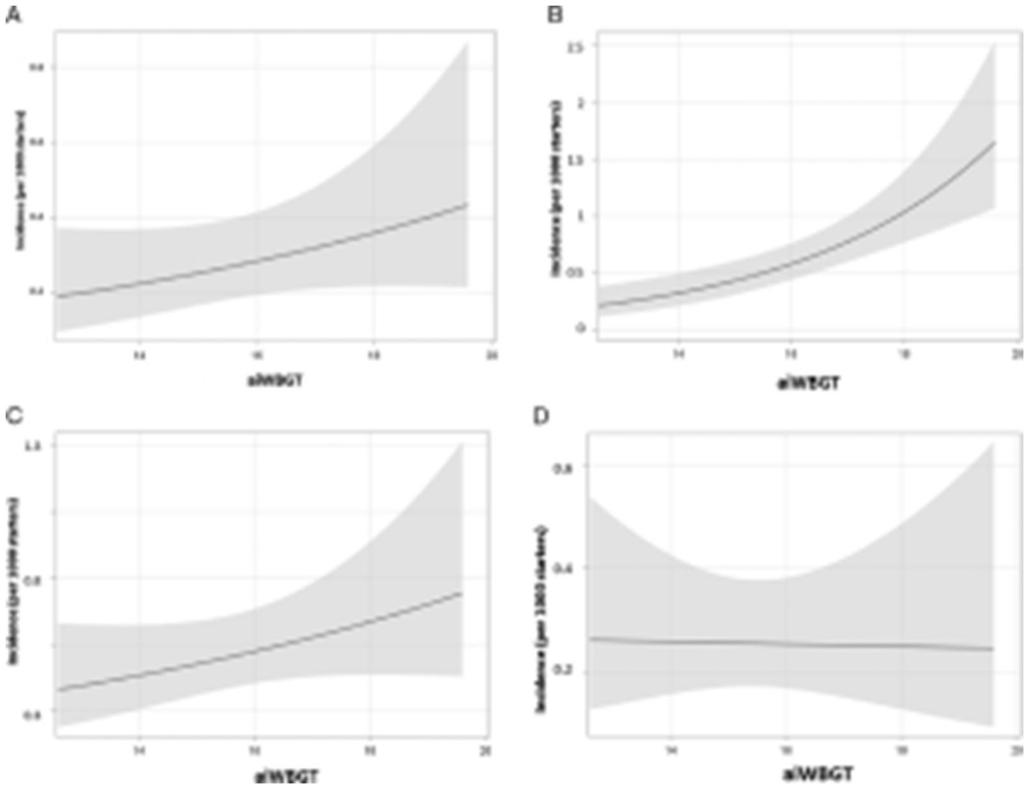

FIGURE 2. A, Serious/life-threatening/death ME incidence for aiWBGT (P = 0.1890). B, Fluid/electrolyte illME incidence for aiWBGT (P < 0.0001). C, Cardiovascular illME incidence for aiWBGT (P = 0.1741). D, Respiratory illME incidence for aiWBGT (P = 0.9323). Model for participants 40.88 yr old (average age), cycling at 23.79 km·h−1 (average speed). Wide CI values are indicative of a small sample size at that aiWBGT.

A 2-unit increase was associated with a significantly higher risk of fluid and electrolyte illME (IR = 1.8, 95% CI = 1.4–2.3).

DISCUSSION

In 2014, we reported the first results of a series of SAFER studies in the recreational running population. In these studies, we first documented all ME in runners participating in an ultra- and a half-marathon (8) and then identified risk factors that are associated with the development of these ME (18,19). The clinical relevance of these data is that we were able to identify individuals that are at higher risk for ME during endurance running, design a prerace medical screening and educational program, and then show that we could significantly reduce ME in distance runners by implementing this program (20). More recently, we extended this work to cyclists participating in a single-day 109-km cycling event held annually in Cape Town, attracting approximately 30,000 cyclists (both recreational and elite). In the first study in cyclists (15), we reported an incidence of 5.3 (per 1000 race starters) and 2.1 for all ME and illME, respectively. In the 3-yr study, there were three cardiac arrests and one death (2.9 and 1.0 per 100 000 starters, respectively). We also showed that the most common illME, by main organ system, were fluid/electrolyte abnormalities (IR = 0.6), cardiovascular abnormalities (IR = 0.5), and respiratory abnormalities (IR = 0.2). The next step is to determine the risk factors associated with illME in cyclists so that we can design and implement intervention strategies to reduce ME, which is the focus of this study.

In this study, we show that the independent risk factors associated with illME determined were slower cycling speed and warmer, more humid environmental conditions (higher aiWBGT). Also, risk factors associated with serious life-threatening illME or death ME were older cyclists (>50 yr) and slower cyclists, and factors associated with increased risk for common illME by organ system were as follows: 1) fluid and electrolyte disorders (females, slower cyclists, and higher aiWBGT), 2) cardiovascular system (older age), and 3) respiratory disease (no risk factors determined).

The overall IR of illME over the 3 yr was 2.1 per 1000 starters. In previous endurance cycling event studies, the same definitions and methods were not used, and therefore this IR cannot be accurately compared with any other cycling studies. We show that the risk factors associated with all illME were slower cycling speed and higher aiWBGT. Slower cycling speed was a risk factor associated with all illME. We are not aware of any study where cycling speed as a possible risk factor for illME was investigated. In only one study in cycling in a multiday cycling event, no previous cycling experience was associated with a 1.8 times risk of having an injury or illness (14). However, we have previously shown that both faster and slower running speed was associated with an increased risk of any ME in a 56-km distance endurance running event (18). We did not investigate reasons for the association between slower cycling speed and risk of illME, but we can speculate that slower cycling speed, independent of age and sex, may be associated with suboptimal race preparation, less experience, or perhaps underlying acute or chronic illness. We suggest that these, and other factors, could be explored in future studies.

Overall WBGT has been investigated in studies as a measure of environmental conditions (21,22), but environmental risk, to our knowledge, has not been calculated using individual WBGT exposure to reflect each specific participant's environmental exposure during an event. aiWBGT takes into account the specific environmental conditions during an event that a participant is exposed to, which is especially important in an event such as the Cape Town Cycle Tour, where there is a staggered start, and participants can take up to 7 h to complete. We conclude that individualized environmental exposure, rather than an average exposure for the entire starting field, is important and affects the risk of illME in cyclists.

We have shown that fluid and electrolyte disorders, particularly dehydration, are the most common illME in this endurance event, accounting for 28.4% (60/211) of all illME (15). In this study, we show that exposure to a higher aiWBGT was a risk factor associated with fluid and electrolyte ME. This is not surprising because previous studies in endurance athletes have found that fluid and electrolyte disorders are often associated with poor hydration habit (23,24) and poor strategies for heat acclimatization (23,24). Our data show that higher aiWBGT is a risk factor associated with fluid and electrolyte disorders. In other studies in runners, being female and running at a slower speed were additional factors associated with an increase in these disorders. Although running and cycling are very different sports, both of these studies examined endurance athletes and therefore provide further information regarding these risk factors. Our findings suggest that education, focusing on hydration strategies and energy replacement, and heat acclimatization are important preventative strategies to reduce illME in endurance cyclists.

The second most common organ system affected by illME in this endurance sports event is the cardiovascular system (23.2% of all illME). We previously reported that postural hypotension and other CV illness made up 39% (19/49) of all cardiovascular illME (15), whereas serious life-threatening cardiovascular illnesses accounted for 61% (30/49) of cardiovascular illME, and these were predominantly ischemic heart disease and arrhythmias (15). In this study, we show that older age was associated with an increased risk of all cardiovascular illME. Previous studies show that the incidence of sudden cardiac death or death, although infrequent, is higher in older athletes, and the most common cause is underlying ischemic heart disease (25–28). Our findings suggest that any intervention to reduce cardiovascular illME needs to focus on prescreening for underlying CVD and risk factors for CVD in older cyclists and combine this with an educational intervention particularly in events that take place in warmer and humid environmental conditions.

illME affecting the respiratory system were the third most common in this event (11.8%) and in this study consisted predominantly of infections (68% of respiratory illME) (15). We could not identify any specific risk factors associated with respiratory illME. This analysis was however limited by the small sample size of respiratory illME, and we suggest that in future studies a larger cohort of respiratory illnesses in cycling events might result in the identification of risk factors associated with respiratory illME.

The main strength of this study is that, to our knowledge, this is the largest study to identify risk factors associated with illME in recreational cyclists during a single-day event. Furthermore, data were reported and analyzed according to the 2019 consensus statement for mass community-based participation events (9), allowing for future comparisons to be made. Not only was the medical data collected in a standardized format by medical doctors and nurses, but the race entry data and the race day data were also recorded accurately. We provide novel insights into factors associated with illME that could lead to the design and implementation of prevention programs to reduce illME in this population. A further strength is that we calculated a novel individualized environmental exposure (aiWBGT) for each cyclist, and this was included into all illME analysis. This was found to be a significant risk factor for illME. We are not aware of any other study where an individualized measure of environmental exposure during an event was examined as a risk factor.

We acknowledge that this study was a retrospective analysis of data collected over 3 yr. However, we used a standardized data collection form that was very similar to the data collection form in the 2019 consensus document. This made it possible for us to easily translate the data from our collection form to that required by the 2019 consensus document. Our sample size was large enough to identify risk factors for serious life-threatening illME (novel data), but we acknowledge that our numbers were too small to identify risk factors associated with sudden cardiac arrest or death. We recommend that future studies investigate the risk factors associated with sudden cardiac death in a much larger sample. We also only had demographic and race day factors available for investigation; future studies should attempt to investigate other factors such as participant weight, race experience, bicycle type, and prerace medical screening data.

In this study, we report novel independent risk factors associated with illME in cyclists participating in a 109-km mass community-based endurance cycling event. A higher risk of all illME was associated with slower cycling speed and warmer, more humid environmental conditions. For specific common illME, females, older age, and slower cycling speed were associated with a higher risk. The identification of these risk factors is important 1) to assist medical teams on race day to prepare for certain illME based on the profile of cyclists and 2) to design and implement illness prevention programs for these and similar cycling events.

What are the new findings?

- Slower cycling speeds and warmer, more humid environmental conditions are associated with a higher incidence of illME in cycling events.
- Older age and slower cycling speed were associated with an increased incidence of all serious life-threatening/death ME.
- Warmer, more humid environmental condition (higher average individual WBGT) was a risk factor associated with illness-related fluid and electrolyte ME.

How might it affect clinical practice in the near future?

- The results of this study provide valuable insight into the risk factors for illME in a mass community-based participation cycle race.
- Race organizers and race medical directors can preempt the risk of illME on race day, based on the profiles of entrants and expected race day environmental conditions.
- These data can assist in the planning and delivery of medical care on race day, as well as direct prerace medical advice to race participants.
- Prerace preventative programs can be targeted to specific groups; for example, prevention programs aimed at reducing fluid/electrolyte preventative ME could be tailored to females and older age entrants, particularly when hotter/more humid conditions are expected.
- Prerace medical screening and educational intervention programs that specifically address the risk factors identified by this study require further investigation.

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The authors declare that there are no competing interests. No additional data are available in this article.

The results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation. The results of the present study do not constitute endorsement by the American College of Sports Medicine.

Author contribution: N. S. carried out data interpretation and drafted (first draft) and edited the manuscript. M. S. was responsible for the overall content as guarantor, study concept, study planning, data cleaning, data interpretation, manuscript first draft, manuscript editing, and fund facilitation. J. K. carried out study concept, study planning, data collection, data cleaning, data interpretation, and manuscript editing. D. C. J. R. carried out study concept, study planning, data interpretation, and manuscript editing. S. S. carried out study planning, data analysis including statistical analysis, data interpretation, and manuscript editing. E. J. carried out study planning, data analysis including statistical analysis, data interpretation, and manuscript editing.

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