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Strategies and factors associated with preparing for competing in the heat: a cohort study at the 2015 IAAF World Athletics Championships

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ABSTRACT

Purpose Assess exertional heat illness (EHI) history and preparedness in athletes competing in a World Athletics Championships under hot/humid conditions and identify the factors associated with preparedness strategies.

Methods Of the 207 registered national teams invited to participate in the study, 50 (24%) accepted. The 957 athletes (49% of all 1965 registered) in these teams were invited to complete a precompetition questionnaire evaluating EHI history, heat stress prevention (heat acclimatisation, precooling and hydration) and recovery. Responses from 307 (32%) athletes were separated in field events, sprints, middle-distance and long-distance running, and decathlon/heptathlon for analysis.

Results 48% of athletes had previously experienced EHI symptoms and 8.5% had been diagnosed with EHI. 15% heat acclimatised (~20 days) before the championships. 52% had a precooling strategy, ice slurry ingestion (24%) being the most prevalent and women using it more frequently than men ($p=0.005$). 96% of athletes had a fluid consumption strategy, which differed between event categories ($p<0.001$). The most common volumes planned on being consumed were 0.5–1 L (27.2%) and ≥ 2 L (21.8%), water being the most frequent. 89% of athletes planned on using at least one recovery strategy. Female sex ($p=0.024$) and a previous EHI diagnosis increased the likelihood of using all 3 prevention strategies ($p<0.001$).

Conclusions At a World Championships with expected hot/humid conditions, less than one-fifth of athletes heat acclimatised, half had a precooling strategy and almost all a hydration plan. Women, and especially athletes with an EHI history, were more predisposed to use a complete heat stress prevention strategy. More information regarding heat acclimatisation should be provided to protect athlete health and optimise performance at major athletics competitions in the heat.

INTRODUCTION

The 15th International Association of Athletics Federations (IAAF) World Championships were held in Beijing (China) from 22 to 30 of August 2015. Based on weather patterns from the previous 10 years, it was anticipated that the event would be held in warm/hot and humid conditions, with mean and maximum daily temperatures of ~26°C and ~33°C, respectively, and a relative humidity of ~73%.¹ Under such environmental conditions, there is potential for both the performance and health of athletes to be compromised, leading to

impairments in exercise capacity and possibly to exertional heat illness (EHI).

From a performance perspective, the influence of hot environmental conditions is largely related to exercise duration. For example, an increase in core and particularly muscle temperature is beneficial to performance (ie, the production of maximal force and power) during brief explosive efforts such as jumping and sprinting.² In contrast, large increments in core and skin temperature (ie, thermal strain) are associated with impaired endurance performance due to an increase in thermoregulatory function exacerbating the cardiovascular response.^{3,4} Severe dehydration via excessive sweating further exacerbates the influence of heat stress on performance through a loss of plasma volume, causing hypovolaemia.⁵

The development of EHI may be viewed as occurring along a continuum, from relatively mild symptoms such as muscle cramps to heat exhaustion and to the more serious and life-threatening condition of exertional heatstroke.^{6,7} Although hyperthermia and dehydration can influence aerobic performance and lead to EHI, specific interventions such as heat acclimatisation and precooling can allow athletes to minimise the loss in performance associated with competing in hot ambient conditions.⁸ The IOC recently highlighted the need to characterise the sport and event-specific profiles of international athletes competing in the heat in a consensus statement.⁹ Indeed, while core temperature and heart rate have been monitored in amateur runners during a half-marathon¹⁰ and the impact of weather on marathon performance has been described for different populations,¹¹ it remains unknown whether elite track and field athletes follow so-called ‘best practice’ approaches when preparing to compete in the heat. Understanding how elite athletes from various disciplines and global regions prepare for a major competition in the heat may help guide future practice and research.

Therefore, this study aimed to assess the EHI history, preparedness and recovery of athletes competing in the championships under potentially hot/humid conditions, as well as to identify the factors associated with different preparedness strategies. Preparation was assessed based on the athletes training in the heat prior to the championships, along with using precooling and fluid consumption strategies during competition. It was hypothesised

that individuals having experienced EHI and athletes competing in endurance-type events would more commonly adopt heat stress prevention strategies.

METHODS

Participants

A cohort study design was used to collect data during the IAAF World Athletics Championships in Beijing 2015. Of the 207 registered national teams invited to participate in the study, 50 (24%) accepted. The 957 athletes in these teams (49% of the 1965 registered athletes) were invited to complete a *precompetition heat strategy questionnaire*. Information about the purpose of the study was provided to the athletes during the accreditation procedure. A total of 307 (32%) athletes accepted to participate. The athletes were separated in five event categories: field (ie, jumps and throws), sprints (ie, 100, 200, 400 m, including hurdles and relays), middle distance (ie, 800, 1500 and 3000 m steeplechase), long distance (ie, 5000 and 10 000 m, marathon and race walking) and decathlon/heptathlon. The characteristics of the athletes in each event category are presented in [table 1](#). The protocol for the study was approved by the Anti-Doping Lab Qatar Institutional Review Board (F2015000074). All procedures conformed to the standards of the Declaration of Helsinki.

Data collection

Participants completed a *precompetition heat strategy questionnaire* in the days prior to competing in their event after arriving in Beijing. The questionnaire was translated into the six IAAF official languages (English, French, Russian, Japanese, Spanish and Arabic). The questionnaire consisted of seven multiple-choice questions addressing the themes of heat illness, heat acclimatisation (≤ 35 days), cooling, hydration and recovery (see online supplementary appendix). Five of the questions had a section with the possibility for additional information to be provided. The questionnaire was intended to gain an understanding of the approach used by elite athletes and their coaches ahead of a major competition likely to be held in hot and humid conditions. The questionnaire focused on strategies used in the preparation, competition and recovery phases of the championships. Participating athletes completed the questionnaire on print paper, after receiving instructions from on-field researchers. In-championship heat illness was defined according to the consensus on injury and illness reporting in athletics.¹² Newly incurred injuries and illnesses were recorded by national medical teams and/or by physicians on the local organising committee using procedures established at previous championships.^{13 14} Ambient air temperature and Wet Bulb Globe

Temperature (WBGT: Kestrel 4400, Nielsen-Kellerman, Boothwyn, USA) were measured in the warm-up area and stadium throughout each day for the duration of the championships, as well as during the marathon and race walking events.

Definition of heat stress prevention

Four different measures of heat stress prevention were defined: (1) 'Having trained in the heat before the championships', (2) 'Planning to use a precooling method before the competition', (3) 'Planning to consume fluids during the competition', and (4) 'All of (1), (2) and (3)'.

Statistical analysis

Differences of proportions of heat stress prevention strategies over different home continent, sex and event category were examined using χ^2 tests with ϕ as effect size ($\phi=0.1$ was considered a small effect, $\phi=0.3$ a medium effect and $\phi=0.5$ a large effect). An analysis of non-participating athletes was performed by comparing their distribution of home continent, the Human Development Index (HDI),¹⁵ sex and age with the final study group. Examination of potential factors explaining the use of heat stress prevention strategies at the championship was performed using logistic regression analysis. First, analyses were performed with simple models (ie, logistic regression analyses with 1 explanatory variable). Thereafter, analyses were performed with multiple models (ie, logistic regression analyses with several explanatory variables) for each of the four definitions of heat stress prevention. The multiple models were fitted using stepwise elimination of non-significant variables. The explanatory variables were sex, age, home continent, the HDI, event category, availability of medical support before the championships, experience of previous heat-related symptoms, and previously having been diagnosed with EHI. Events for these models were coded into two categories: speed/power (field, sprints and decathlon/heptathlon) and endurance (middle and long distance) events. All statistical calculations were performed using SPSS Statistics for Windows, V.21.0 (IBM Corporation, Armonk, New York, USA). All statistical tests were two-sided and outcomes with $p<0.05$ were regarded as statistically significant. Data are presented as mean \pm SD.

RESULTS

The distribution of athletes completing the questionnaire per continent was 11.1% from Africa, 18.2% from Asia, 2.6% from Australia, 32.9% from Europe, 14.3% from North America and 20.8% from South America. A comparison of the participating and non-participating athletes revealed that while sex showed no significant difference between groups, non-participation was slightly higher in athletes over 25 years ($p=0.040$), in African athletes ($p<0.001$) and among athletes from developing countries according to the HDI ($p=0.037$).

Environmental conditions and EHI

Mean daily temperature and WBGT during the championships were $27\pm 3^\circ\text{C}$ and $24\pm 2^\circ\text{C}$ at 8:00, $31\pm 3^\circ\text{C}$ and $27\pm 2^\circ\text{C}$ at 12:00, and $30\pm 4^\circ\text{C}$ and $25\pm 2^\circ\text{C}$ at 16:00. Five (1.6%) of the athletes participating in the study were diagnosed with symptoms (eg, nausea, vomiting, dizziness, palpitations and syncope) associated with EHI (eg, exhaustion, dehydration) during the championships.

Heat illness symptoms and diagnosis

Approximately half (47.6%) of the athletes responding to the questionnaire reported having previously experienced at least

Table 1 Characteristics of the precompetition heat-strategy questionnaire responders from 50 different national teams during the 2015 IAAF World Championships

Discipline categories	Number of responders	Male	Female	Age (year)
Field events	76	41	35	27 \pm 5
Sprints and hurdles	88	49	39	25 \pm 4
Middle distance	37	21	16	26 \pm 3
Long distance	94	53	41	29 \pm 5
Decathlon/heptathlon	12	8	4	27 \pm 4
Total/mean	307	172	135	27 \pm 5

IAAF, International Association of Athletics Federations.

Table 2 Previous history of symptoms and diagnosis of heat illness in athletes (% of responders) competing in the 2015 IAAF World Championships

	Field	Sprints	Middle distance	Long distance	Decathlon/heptathlon
History of heat illness symptoms					
Cramping	27.6	26.1	16.2	25.5	33.3
Vomiting	7.9	20.5	8.1	10.6	16.7
Nausea	9.2	17.0	8.1	13.8	16.7
Severe headache	14.5	22.7	29.7	11.7	33.3
Collapsing/fainting	3.9	3.4	5.4	9.6	0.0
Other	Dizziness, tiredness, gastrointestinal issues, tachycardia				
History of heat illness diagnosis					
Dehydration	5.3	2.3	5.4	5.3	8.3
Hyponatraemia	0.0	0.0	0.0	0.0	0.0
Heat exhaustion	1.3	1.1	0.0	3.2	8.3
Heat stroke	0.0	3.4	0.0	2.1	0.0

IAAF, International Association of Athletics Federations.

one heat illness symptom, whereas 17% reported two or more symptoms (table 2). Event category influenced the prevalence of experiencing severe headaches during training and/or competing in the heat ($p=0.049$, $\phi=0.18$), with a greater fraction of middle-distance runners and decathlon/heptathlon athletes reporting this symptom. Nausea ($p=0.065$, $\phi=0.11$) and severe headaches ($p=0.079$, $\phi=0.10$) tended to be symptoms more often reported in women than men during training and/or competing in the heat. Of the 26 athletes (8.5%) reporting a previous diagnosis of EHI, 3 (11.5%) reported having been diagnosed with both dehydration and heat exhaustion.

Heat training

In preparation for the championships, 15.3% of the athletes surveyed reported having prepared specifically by training in the heat. No significant differences in heat acclimatisation were observed for home continent, sex and event category. In the field events, 15.8% of athletes trained in a natural hot environment, 17.0% of sprint athletes, 13.5% of middle-distance athletes, 12.8% of long-distance athletes and 16.7% of decathlon/heptathlon athletes also reported following a heat acclimatisation regimen. The length of the regimen varied between 17 ± 10 days (field events), 18 ± 10 days (sprints), 18 ± 11 days (middle distance), 23 ± 10 days (long distance) and 30 ± 0 days (decathletes/heptathletes). In addition, two long-distance athletes reported training indoors in an artificially hot environment (ie, heat acclimation) for 11 and 12 days, respectively.

Precooling

Approximately half (52.4%) of the athletes reported having at least one prearranged cooling strategy, 10.4% having two strategies and 4.9% having three strategies (table 3). Event category influenced the use (or not) of a strategy ($p=0.012$, $\phi=0.19$), as well as use of an ice vest ($p<0.001$, $\phi=0.32$), with a small-to-medium effect on the use of a neck collar ($p=0.055$, $\phi=0.17$) and whole-body cold-water immersion ($p=0.074$, $\phi=0.17$). Women reported using ice slurry or cold drink ingestion ($p=0.005$, $\phi=0.16$) and neck collars ($p=0.050$, $\phi=0.11$) more frequently than did men.

Hydration

The analysis revealed differences among event categories for the volume of fluids planned on being consumed ($p<0.001$,

Table 3 Prearranged cooling, hydration and recovery strategies in athletes (% of responders) competing in the 2015 IAAF World Championships

	Field	Sprints	Middle distance	Long distance	Decathlon/heptathlon
Precooling methods athletes planned on using					
None	61.8	46.6	29.7	43.6	50.0
Ice vest	0.0	0.0	5.4	17.0	16.7
Cold towel	15.8	10.2	18.9	11.7	33.3
Neck collar	0.0	3.4	10.8	3.2	8.3
Whole-body CWI	1.3	3.4	10.8	8.5	8.3
Leg CWI	13.2	12.5	24.3	10.6	25.0
Ice slurry ingestion	15.8	28.4	21.6	25.5	41.7
Other	Cold hat/cap, cold water, ice-massage				
Planned fluid consumption					
None	0.0	13.6	37.8	23.4	0.0
<0.5 L	6.6	9.1	2.7	10.6	0.0
0.5–1 L	43.4	34.1	18.9	11.7	0.0
1–1.5 L	21.1	19.3	8.1	14.9	8.3
1.5–2 L	11.8	13.6	16.2	11.7	0.0
>2 L	17.1	10.2	16.2	27.2	91.7
Planned fluid composition					
Water	90.8	78.4	78.4	62.8	91.7
Electrolytes	35.5	44.3	35.1	58.5	75.0
Carbohydrates	7.9	8.0	16.2	30.9	58.3
Other	Cold tea, green tea, protein, Red Bull, Gatorade				
Planned recovery strategies					
None	15.8	1.1	0.0	11.7	0.0
Active recovery	31.6	47.7	59.5	41.5	66.7
Stretching	43.4	51.1	48.6	46.8	66.7
Contrast immersion	3.9	8.0	13.5	10.6	8.3
CWI	26.3	45.5	59.5	35.1	66.7
Massage	56.6	55.7	67.6	48.9	50.0
Hot water immersion	6.6	8.0	10.8	5.3	8.3
Electrostimulation	5.3	2.3	2.7	1.1	16.7
Compression clothing	7.9	9.1	18.9	20.2	8.3
Other	Icing, cryotherapy, protein, pool recovery				

CWI, cold-water immersion; IAAF, International Association of Athletics Federations.

$\phi=0.56$). The most commonly reported volumes were 0.5–1 L (27.2%) and 2 L or more (21.8%; table 3). The preferred fluid composition for hydration was water, with medium-to-large differences for drinking water ($p<0.001$, $\phi=0.26$), electrolytes ($p=0.004$, $\phi=0.22$) and carbohydrates ($p<0.001$, $\phi=0.34$) between event categories. Women preferred to consume water more than men ($p=0.016$, $\phi=0.14$).

Recovery

Most athletes planned on only using one recovery strategy (26.1%), with 23.5%, 17.9% and 13.7% planning on using two, three and four strategies, respectively, while 7.5% planned on using five or more recovery strategies (table 3). There were differences between event categories in the use (or not) of recovery strategies ($p=0.001$, $\phi=0.24$), including active recovery ($p=0.021$, $\phi=0.19$), cold-water immersion ($p=0.002$, $\phi=0.24$), electrostimulation ($p=0.049$, $\phi=0.18$) and compression garments ($p=0.078$, $\phi=0.17$). Women reported planning the use of recovery strategies more frequently than men ($p=0.017$, $\phi=0.14$), with a greater use of massage therapy ($p=0.025$, $\phi=0.13$).

Explanatory models

The simple model analyses showed that sex (females: 20.0%, males: 11.6%) (odds ratio (OR) 1.90; $p=0.045$), a history of experiencing heat illness symptoms (OR 1.88; $p=0.048$) and a previous diagnosis of EHI (OR 7.27; $p<0.001$) increased the likelihood of training in the heat prior to the championships (table 4). In the multiple model, only the associations between the sex of the athlete and previous EHI diagnosis remained.

The simple model analyses showed that precooling was influenced by sex (females: 57.8% and males: 48.3%) (OR 1.64; $p=0.034$), event category (OR 1.72; $p=0.020$), continent ($p<0.001$), HDI (OR 2.44; $p<0.001$) and having previously been diagnosed with EHI (OR 2.73; $p=0.023$) (table 5). Athletes originating from Asia demonstrated an increased likelihood of employing a precooling strategy (OR 2.33; $p=0.015$), while those from South America showed a reduced likelihood (OR 0.11; $p<0.001$). The multiple analyses showed that the likelihood of using precooling was higher in women (OR 1.92; $p=0.014$) and in athletes from Africa (OR 2.44; $p=0.035$) and Asia (OR 2.66; $p=0.006$), but lower in South American athletes (OR 0.12; $p<0.001$).

Athletes competing in endurance events demonstrated a lower likelihood of using a planned fluid consumption strategy in the simple and multiple analysis models (OR 0.30; $p<0.001$) (table 6).

The simple heat stress prevention model analyses revealed that sex (females: 14.8% and males: 5.2%) (OR 2.61; $p=0.026$), home continent ($p=0.024$) and a previous diagnosis of EHI (OR 8.22; $p<0.001$) were associated with adopting a strategy which included: heat acclimatisation, precooling and a fluid consumption strategy (table 7). Athletes from South America (OR 0.12; $p=0.042$) were less likely to adopt such a strategy. In the multiple model, only athlete sex (OR 2.77; $p=0.024$) and a previous diagnosis of EHI (OR 8.64; $p<0.001$) remained.

DISCUSSION

The aim of this study was to evaluate the history of EHI and preparedness of athletes competing in the 2015 IAAF World Athletics Championships in Beijing under potentially hot/humid ambient conditions, and to identify the factors associated with adopting different heat stress prevention strategies using a pre-competition questionnaire. To the best of our knowledge, this is

the first report describing the preparation of elite-level athletes competing in such a high-profile event. Our results indicate that approximately half of the athletes participating in the study had previously experienced heat illness symptoms (eg, cramping, severe headaches) and 8.5% had been diagnosed with EHI, most commonly dehydration. Only 15% of athletes reported having prepared specifically for the championships by undertaking heat training regimens (mean duration: ~20 days). It was also observed that precooling in a variety of forms was adopted by half of the athletes. The volume of fluids planned on being consumed during competition varied considerably, with field and sprint athletes mostly planning on consuming 0.5–1 L, middle-distance and long-distance athletes a mixture of volumes, and decathletes/heptathletes more than 2 L. The composition of the fluids consumed was mainly water with some electrolytes. A quarter of the athletes planned on using one recovery strategy and another quarter a combination of strategies (eg, massage, stretching, cold-water immersion). These data indicate that fluid consumption was an integral part of the approach for almost all athletes (96%) competing at the World Championships, followed by precooling (52%) and training in the heat (15%). The most common explanatory variables associated with adopting multiple heat stress prevention strategies were a previous diagnosis of EHI and the sex of the athlete, with women displaying a higher likelihood.

Our data demonstrate a personal history of cramping as being the most prevalent heat illness symptom reported, with a relatively low incidence of having previously been diagnosed with severe EHI (ie, heat stroke; table 2). During the 2015 Championships, five of the athletes participating in the study were reported as having experienced issues related to EHI. Of these athletes, two had previously experienced symptoms related to EHI during training and/or competing in the heat; however, none had been diagnosed with EHI. Three of the athletes participated in endurance events, one in a middle-distance race and the other in a field event. Two athletes had prepared by heat acclimatising, three had a precooling strategy, all had a hydration plan, and four a recovery strategy. Interestingly, the two athletes who had previously experienced EHI symptoms are the ones who heat acclimatised. Given that several risk factors are linked with the development of EHI—environmental factors, medications, drug use, compromised health status and genetic conditions—it is difficult to identify why these athletes

Table 4 Explanatory models for training in the heat (ie, heat acclimatisation/acclimation) prior to the 2015 IAAF World Championships presented as ORs (95% CI) calculated by simple and multiple logistic regression analyses

	95% OR	
	Prechampionship heat acclimatisation	
	Simple models	Multiple model
Sex	1.90 (1.01 to 3.56) ($p=0.045$)	1.97 (1.02 to 3.82) ($p=0.043$)
Age	NS	
Continent (reference: Europe)	NS ($p=0.057$)	
Human Development Index (reference: very high-level countries)	NS	
Lower developmental levels (very low-level, low-level, high-level countries)		
Event category (reference: speed/power events)	NS	
Endurance events		
Prechampionships medical support available	NS	
Experience of heat-related symptoms	1.88 (1.01 to 3.51) ($p=0.048$)	
Previous EHI diagnosis	7.27 (3.11 to 16.97) ($p<0.001$)	7.47 (3.15 to 17.69) ($p<0.001$)

CI, confidence interval; EHI, exertional heat illness; IAAF, International Association of Athletics Federations; NS, not significant; OR, odds ratio.

Table 5 Explanatory models for using a precooling strategy during the 2015 IAAF World Championships presented as ORs (95% CI) calculated by simple and multiple logistic regression analyses

	95% OR	
	In-championship use of precooling strategy	
	Simple models	Multiple model
Sex	1.64 (1.04 to 2.58) (p=0.034)	1.92 (1.14 to 3.23) (p=0.014)
Age	NS	
Continent (reference: Europe)	p<0.001	p<0.001
Africa	2.02 (0.91 to 4.53) (p=0.086)	2.44 (1.07 to 5.59) (p=0.035)
Asia	2.33 (1.18 to 4.62) (p=0.015)	2.66 (1.32 to 5.36) (p=0.006)
Australia	3.31 (0.64 to 17.20) (p=0.154)	2.92 (0.55 to 15.44) (p=0.206)
North America	1.45 (0.71 to 2.96) (p=0.305)	1.51 (0.74 to 3.12) (p=0.261)
South America	0.11 (0.05 to 0.29) (p<0.001)	0.12 (0.05 to 0.30) (p<0.001)
Human Development Index (reference: very high-level countries)	2.44 (1.53 to 3.88) (p<0.001)	
Lower developmental levels (very low-level, low-level, high-level countries)		
Event category (reference: speed/power events)	1.72 (1.09 to 2.72) (p=0.020)	
Endurance events		
Prechampionships medical support available	NS	
Experience of heat-related symptoms	NS	
Previous EHI diagnosis	2.73 (1.15 to 6.48) (p=0.023)	

CI, confidence interval; EHI, exertional heat illness; IAAF, International Association of Athletics Federations; OR, odds ratio.

Table 6 Explanatory models for using a fluid consumption strategy during the 2015 IAAF World Championships presented as ORs (95% CI) calculated by simple and multiple logistic regression analyses

	95% OR	
	In-championship use of hydration strategy	
	Simple models	Multiple model
Sex	NS	
Age	NS	
Continent (reference: Europe)	NS	
Human Development Index (reference: very high-level countries)	NS (p=0.056)	
Lower developmental levels (very low-level, low-level, high-level countries)		
Event category (reference: speed/power events)	0.27 (0.15 to 0.50) (p<0.001)	0.27 (0.15 to 0.50) (p<0.001)
Endurance events		
Prechampionships medical support available	NS	
Experience of heat-related symptoms	NS	
Previous EHI diagnosis	NS	

CI, confidence interval; EHI, exertional heat illness; IAAF, International Association of Athletics Federations; OR, odds ratio.

experience EHI symptoms, despite preparing for the championships by training in the heat. Although there may be an increased likelihood of experiencing EHI when participating in high-intensity endurance events, our data suggest that athletes in shorter races and field events are also likely to be susceptible to EHI. Additional research is thus warranted to determine the potential markers indicative of EHI predisposition.

Nevertheless, <2% of the athletes participating in the study were reported as having experienced EHI symptoms. This may relate to the WBGT remaining between 23°C and 28°C during the championships, a range associated with a high but not extreme ($\geq 28^\circ\text{C}$) risk for EHI.^{16 17} The WBGT is an environmental heat stress index and not a representation of human heat strain. As such, it may not represent the environmental conditions in which the limit of compensation is exceeded in different events, which depends on several factors (eg, metabolic heat production, athlete morphology, acclimatisation state and

clothing).⁸ Nevertheless, these data are in line with a previous surveillance study examining the risk of heat illness in professional beach volleyball over a 3-year period.¹⁸ The authors observed that the risk of significant heat illness was very low, even though hot and humid conditions were encountered frequently, with only three cases of a medical forfeiture related to heat stress. This most likely reflects the high level of fitness of elite athletes and some degree of adaptation to heat.

It has been suggested that heat acclimatisation is the most important intervention one can adopt to reduce physiological strain and optimise performance is to heat.⁸ Heat acclimatisation reduces the risk of EHI, as well as induces physiological adaptations that improve thermoregulation, attenuate physiological strain and improve aerobic performance in warm/hot environments.^{19 20} It is interesting to note that a similar or even slightly lower per cent of middle-distance and long-distance athletes reported having specifically prepared for the championships by

Table 7 Explanatory models for the use of all three heat stress prevention strategies (ie, training in the heat, planning to use a precooling method and fluid consumption strategy) prior to and during the 2015 IAAF World Championships presented as ORs (95% CI) calculated by simple and multiple logistic regression analyses

	95% OR	
	In-championship use of heat stress prevention strategies	
	Simple models	Multiple model
Sex	2.61 (1.12 to 6.06) (p=0.026)	2.77 (1.14 to 6.68) (p=0.024)
Age	NS	
Continent (reference: Europe)	p=0.024	
Africa	0.46 (0.10 to 2.19) (p=0.331)	
Asia	0.28 (0.06 to 1.27) (p=0.099)	
Australia	4.45 (0.94 to 21.03) (p=0.060)	
North America	1.17 (0.41 to 3.35) (p=0.768)	
South America	0.12 (0.02 to 0.93) (p=0.042)	
Human Development Index (reference: very high-level countries)	NS	
Lower developmental levels (very low-level, low-level, high-level countries)	NS	
Event category (reference: speed/power events)	NS	
Endurance events	NS	
Prechampionships medical support available	NS	
Experience of heat-related symptoms	NS	
Previous EHI diagnosis	8.22 (3.20 to 21.16) (p<0.001)	8.64 (3.26 to 22.85) (p<0.001)

CI, confidence interval; EHI, exertional heat illness; IAAF, International Association of Athletics Federations; OR, odds ratio.

training in the heat, relative to other event categories. Given that longer duration events are the ones for which heat acclimatisation is most highly recommended,⁸ it was anticipated that a greater fraction of these athletes would have acclimatised. However, given that our data were separated by continent rather than country, it was not possible to determine precisely where the athletes originated from. It is thus conceivable that many athletes live and train in warm/hot summer conditions and did not report having specifically heat acclimatised. Although less than one-fifth of all athletes surveyed reported undertaking a heat acclimatisation regimen, few experienced EHI during the championships while competing in the ~28°C and ~55% relative humidity conditions. While these conditions can be considered warm to hot, they may not be overly oppressive for well-trained individuals by virtue of regularly increasing thermoregulatory strain when training at high intensities, and consequently developing some heat adaptation.¹⁹

Indeed, well-trained individuals exercising at the same relative intensity, but at a higher metabolic rate than untrained individuals, experience a greater rate of heat storage,^{21 22} but fatigue at similar^{23 24} or higher core temperatures.^{25 26} Accordingly, adaptations related to regular high-intensity training may allow for higher rates of whole-body heat accumulation before a reduction in work rate occurs.²⁷ Moreover, aerobically fit individuals heat acclimatise more rapidly than those who are less fit and may have a reduced susceptibility to heat injury/illness (Gardner *et al*, 1996). Given that short-term heat acclimatisation (<7 days) provides some performance-enhancing benefits,²⁸ athletes competing in the World Championships may have adapted to the heat during outdoor training sessions in the lead-up to their event while in Beijing, thus reducing the susceptibility to EHI and optimising performance. In the current study, the variable associated with a greater likelihood of training in the heat in preparation for the championships was a previous diagnosis of EHI, whereas originating from South America was associated with a lower likelihood (table 4). These observations highlight the complexity and numerous factors that influence the preparation strategy of elite athletes. Therefore, it seems important

that all athletes receive appropriate information ahead of a major event expected to take place in hot and/or humid conditions regarding various preparation strategies, regardless of their country of origin, sex and EHI history.

Precooling is an intervention that is becoming increasingly popular with athletes looking to reduce thermal strain, minimise fatigue and accelerate postexercise recovery. By cooling the skin prior to competition (eg, ice vest), athletes can reduce cardiovascular strain for a short period after the onset of exercise in the heat.²⁹ When whole-body cooling (eg, cold-water immersion) is implemented, a decrease in organ and skeletal muscle temperature occurs. Although precooling in its various forms (ie, internal and external) is interesting and appears to have been adopted by several athletes at the 2015 World Championships, the effectiveness and practicality of various cooling techniques, along with the physiological mechanisms underpinning the improvements in performance, require further investigation.^{29 30} During the championships, the factors associated with a higher likelihood of precooling were a previous diagnosis of EHI, home continent (Africa and Asia), a lower level on the HDI, sex (females 58% vs males 48%) and participating in endurance events (table 5). In addition to showing a lower likelihood of heat acclimatisation, athletes from South America also showed a very low likelihood of using precooling techniques. This most likely reflects a combination of factors, from the number of athletes participating in endurance events, to the sex of these athletes, and a previous diagnosis of EHI. Accordingly, further research is required to better understand how these factors, along with socioeconomic considerations, interact to influence the preparation and use of various heat stress countermeasures in athletes from different continents, as well as specific countries in the lead-up to a major championships.

Athletes performing exercise in warm/hot and humid environments have elevated sweat rates which can result in large body water and electrolyte deficits, exacerbating the performance impairments associated with heat stress.⁵ Athletes competing in the championships may have been aware of the impact that hydration status may have on performance and recovery, as more

than 80% had a fluid consumption strategy (table 3). This was especially noticeable in the decathletes and heptathletes spending the better part of an entire day on the track and field, consuming water, as well as electrolytes and carbohydrates. However, it is not possible to determine from the current data if the planned hydration strategy of the athletes was different from their usual strategy in cooler environments. Interestingly, endurance athletes had a lower likelihood of adopting a fluid consumption strategy than speed/power athletes (table 6). However, this most likely relates to the decathletes and heptathletes having been included in the speed/power athlete category of the explanatory models and the nature of the question, which for some could have included the warm-up and cool down (eg, sprints).

When combined into a heat stress prevention strategy using training in the heat, precooling and having a fluid consumption strategy, South American athletes appeared to be at a very low likelihood of adopting such a strategy (table 7). However, the previous diagnosis of EHI increased the likelihood of using a combined heat stress prevention strategy eightfold.

Recovery between events/heats during an athletics competition is essential for optimising physical and mental performance. With a host of recovery options such as water immersion, compression clothing, cryotherapy, sports massage and electrostimulation,^{31–34} it is not surprising to have observed that ~25% of the athletes use one recovery strategy and ~63% at least two recovery strategies (table 3). Although there exist many potential strategies to use during competition, the ones most frequently employed were massage, active recovery, stretching and cold-water immersion.

In summary, only 15% of the athletes surveyed prepared by training in the heat ahead of the 2015 IAAF World Championships in which hot/humid conditions were expected. Approximately half had a precooling strategy, 96% a fluid consumption strategy and over 89% a recovery strategy. Although most athletes did not heat acclimatise prior to the championships, <2% experienced EHI symptoms. This may be attributed to their high level of fitness, partly conferring adaptations similar to heat acclimatisation, and to the other strategies and interventions employed during competition. Having previously experienced EHI and being female were strongly associated with using one or multiple heat stress prevention strategies. Nevertheless, it is recommended that information regarding heat acclimatisation as the primary countermeasure to protect athlete health and optimise performance be disseminated ahead of competitions to be held in hot/humid conditions to allow for adequate preparation.

Study strengths and limitations

The major strength of this study is that, to the best of our knowledge, it is the first to examine the history of EHI and preparedness of elite-level athletes competing in a World Championships in the heat, as well as to evaluate the predictors associated with using heat stress preventing strategies. It should be noted that there exist differences between a clinical diagnosis of EHI and 'feeling sick/uncomfortable in the heat'. Since these concepts are not synonymous, the diagnostic criteria for EHI at major athletics competitions should be agreed on and uniformly applied. Although the overall response rate was relatively low (32.1%), the survey was designed to minimally disrupt the athletes. Moreover, the study was conducted during a period of an intense doping debate in athletics, which may have led to some athletes being reluctant to answer health/medical questionnaires. Accordingly, the response rate can be regarded as acceptable. Additional insights regarding the completion of this study are addressed in a companion paper.³⁵

What is already known on this topic?

- ▶ Specific interventions such as heat acclimatisation, pre-cooling and adopting a hydration strategy allow for optimising performance when competing in hot/humid environmental conditions.
- ▶ Athletic events undertaken in the heat increase the risk of exertional heat illness through the development of hyperthermia and severe dehydration.

What are the new findings?

- ▶ Only 15% of athletes heat acclimatised ahead of the 2015 IAAF World Championships in which hot/humid conditions were expected, ~50% had a pre-cooling strategy, 96% a fluid consumption strategy and over 89% a recovery strategy.
- ▶ A previous diagnosis of exertional heat illness and the female sex were associated with an increased likelihood of using one or multiple heat stress prevention strategies.

How might it impact clinical practice in the near future?

- ▶ Information regarding heat acclimatisation as the primary countermeasure to protect athlete health and optimise performance should be provided to the athletes and their support staff ahead of competitions to be held in hot/humid conditions to allow for adequate preparation.
- ▶ Athletes previously experiencing heat illness symptoms and those having been diagnosed with exertional heat illness are more likely to consider heat acclimatisation prior to competing under heat stress.

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Competing interests None declared.

Ethics approval The study was approved by the Anti-Doping Laboratory Qatar Institutional Review Board and conformed to the current Declaration of Helsinki guidelines.

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