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Human Kinetics
ORIGINAL INVESTIGATION

Heat Preparation and Knowledge at the World Athletics Race Walking Team Championships Muscat 2022

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Purpose: To assess elite racewalkers' preparation strategies, knowledge, and general practices for competition in the heat and their health status during the World Athletics Race Walking Teams Championships (WRW) Muscat 2022. ***Methods:*** Sixty-six elite racewalkers (male: n = 42; mean age = 25.8 y) completed an online survey prior to WRW Muscat 2022. Athletes were grouped by sex (males vs females) and climate (self-reported) they live/trained in (hot vs temperate/cold), with differences/relationships between groups assessed. Relationships between ranking (medalist/top 10 vs nonmedalist/nontop 10) and precompetition use of heat acclimation/acclimatization (HA) were assessed. ***Results:*** All surveyed medalists (n = 4) implemented, and top 10 finishers were more likely to report using (P = .049; OR = 0.25; 95% CI, 0.06%–1%), HA before the championships. Forty-three percent of athletes did not complete specific HA training. Females (8% [males 31%]) were less likely to have measured core temperature (P = .049; OR = 0.2; 95% CI, 0.041–0.99) and more likely to not know expected conditions in Muscat (42% vs 14%; P = .016; OR = 4.3; 95% CI, 1%–14%) or what wet bulb globe temperature is (83% vs 55%; P = .024; OR = 4.1; 95% CI, 1%–14%). ***Conclusions:*** Athletes who implemented HA before the championships tended to place better than those who did not. Forty-three percent of athletes did not prepare for the expected hot conditions at the WRW Muscat 2022, primarily attributed to challenges in accessing and/or cost of equipment/facilities for HA strategies. Further efforts to bridge the gap between research and practice in this elite sport are needed, particularly in female athletes.

***Keywords**:* in-competition, heat adaptation, endurance, barriers

Exercise in the heat can elicit considerable physiological and perceptual strain.[1,2] Large increases in core ([Tc] ~2.5 to 2.5 °C[3]) and/or skin temperatures (~5 °C),[2] alongside dehydration induced by plasma volume loss,[4] can conspire to compromise endurance performance.[3,5] However, high Tc can present in elite athletes competing in hot-humid environments (eg, 41.4–41.5 °C[6–8]) without copresentation of exertional heat illness or stroke (EHI/S) pathologies.[9] Yet, a Tc ≥ 40.0 °C is still associated with increased risk of EHI/S (and diagnoses thereof[10]), which remains a leading cause of sudden death in athletes.[11,12]

Athletes at the International Amateur Athletic Federation (IAAF) World Championships Doha 2019 (Doha 2019) who performed even a modest amount (eg, 5 d) of heat acclimation/acclimatization (HA), placed higher than those who did not, and were less likely to require medical attention for EHI/S-related pathologies.[6] Adoption of HA within training (15% 2015 IAAF Championships; 38% 2016 Union Cycliste Internationale Road World Cycling Championships; 63% Doha 2019), while increasing, is still not implemented by all athletes.[6,13,14] Open access guidelines,[15] consensus statements,[16,17] and governing body disseminated education initiatives[6] endorsing evidence-based heat preparation strategies (including HA) are available to all athletes (and their teams). Despite this, logistical, practical, and financial barriers continue to prevent adoption of HA practices for many athletes.[18] In addition, a lack of self-reported knowledge among elite athletes and their practitioners regarding gold-standard heat preparation strategies has recently been reported (including biologically implausible assumptions).[19] This is despite robust educational efforts tailored to simplify this knowledge for athletes and practitioners (eg, "Beat the Heat" leaflets produced by World Athletics[6]). These challenges and/or barriers may in part explain the lack of universal adoption of HA.

Sport is a global business worth an estimated US$500 billion in 2020 and projected to be worth over US$700 billion in 2026.[20] Such globalization alongside global warming[21] increases the likelihood of elite athletic competition in extremes of heat and/or humidity. The latter is important, given major events such as Doha 2019 were planned with midnight start times,[22,23] and Tokyo 2020ne Olympic road races were relocated to cooler locations (Tokyo to Sapporo),[24] in an attempt (largely unsuccessful) to source temperate competition environments. Indeed, the Tokyo 2020ne Olympic road-race events saw air temperatures of 25 °C to

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34 °C (wet bulb globe temperature [WBGT]: 24–31 °C) despite being moved to a "cooler" climate (Sapporo).[25] The 2022 World Athletics Race Walking Teams Championships (WRW) were held in Muscat, Oman (March 4–5, 2022). Historical weather data predicted average race-start environmental temperatures of 22.5 °C (morning) and 25.5 °C (evening); however, the maximum observed in-race temperatures during the championships were 31.3 °C (ambient temperature; WBGT: 28.6 °C). Athletes failing to prepare for the highest historical race-start temperature (26 °C) may have been ill-prepared for actual race-day conditions. Given Doha 2019 saw 23% of road-race athletes experience a medical event, despite road races' starting close to midnight (overnight WBGT highest: 32 °C),[6] it appears prudent to understand the heat-related preparatory strategies of the athletes at the WRW, given the actual versus expected environmental conditions encountered, alongside the post-COVID-19 pandemic nature of the Championships.[26–29]

Therefore, this study aimed to survey elite athletes during the WRW to evaluate their heat preparation strategies and knowledge, general or specific practices, and health status before the event. Related to this, sex differences and the influence of the athletes' self-reported climate where they live/train (hot or temperate/cold) were also explored.

Methods

Participants

Elite racewalkers competing in the WRW (Muscat, Oman; March 4–5, 2022) were recruited, predominantly via World Athletics official channels, during athlete registration at the event, and through the researchers' network. Eligibility included both sexes competing in a championship event (10, 20, and 35 km). All procedures were approved by the Human Research Ethics Committee at Southern Cross University (2022/010), in the spirit of the Declaration of Helsinki. All participants provided informed consent before participating. After excluding incomplete, invalid, and replicate survey completions, 66 survey completions were suitable for analysis. Participant characteristics and demographic information are presented in Table 1. Race date/time and environmental conditions are provided in Table 2.

Table 1 Participant Characteristics and Demographics

	Male	Female	Total
n	42	24	66
Age, y	26.7 (5.9)	24.3 (7.1)	25.8 (6.4)
Height, m	1.76 (7.2)	1.65 (6.0)	1.72 (8.6)
Body mass, kg	64.5 (8.2)	53.8 (7.2)	60.6 (9.4)
Live/train in hot climate, n			
Yes	16	7	23
No	26	17	43
Race, n			
10 km	4	8	12
20 km	15	4	19
35 km	23	12	35

National team	n	%
Italy	16	24.2
Australia	11	16.7
Japan	7	10.6
United States	6	9.1
Spain	5	7.6
Brazil	4	6.1
Mexico	4	6.1
Ecuador	2	3.0
Oman	2	3.0
Canada	1	1.5
France	1	1.5
Great Britain and Northern Ireland	1	1.5
India	1	1.5
Ireland	1	1.5
South Africa	1	1.5
Sweden	1	1.5
Unknown	2	3.0

Note: Age, height, and body mass data values are expressed as mean (SD). Environment and race are expressed as absolute values.

Design

This study involves a single cross-sectional online survey-based design. The survey was created using an online resource (https://www.qualtrics.com/uk/, Qualtrics[XM]).

Survey

The survey was created, revised, and approved by the authors with themes aligned to the HA/heat mitigation strategies used in preparation for (during and pre) the event, history of heat illness, supplement/medication use, and athlete health/history considerations. The questionnaire was translated from English into 6 other languages (French, Italian, Japanese, Portuguese, Russian, and Spanish) by the research team. Survey responses underwent back translation, also performed by the research team (including at least one native speaker and a topic expert). After piloting and revisions, the finalized survey contained a maximum of 41 questions (potentially less depending on answers) and can be found in full within the Supplementary Material (available online). Athletes were informed to complete the survey independently (ie, without the help of a coach/team member) on arrival at the Championship location.

Survey Analyses

Raw data were exported to Microsoft Excel. Data were analyzed descriptively due to the cross-sectional and observational research design. All responses were coded (ie, assigned a number) based on the answers provided. Questions including open-ended options were examined with inductive content analysis ensuring data familiarization and irrelevant/incorrect information were grouped accordingly. Data from questions were divided into subsections of the survey:

1. Characteristics and demographic information.
2. Personal experience in the heat.
3. Preparation for the heat for this World Championship.
4. Association between HA use and performance (ie, ranking).
5. Personal knowledge and perceptions of HA and related practices.
6. Recent illness and general health.
7. Barriers to implementing HA.

Table 2 Race Date, Start Time, and Starting Environmental Conditions (With Minimum to Maximum in-Race Range)

Race	Date	Time (start)	Starting environmental conditions: Ambient temperature, °C (min–max)	WBGT, °C (min–max)	RH, % (min–max)
10-km women	March 4, 2022	07:58:19	24.5 (24.5–27.2)	24.3 (24.2–26.3)	73.3 (64.7–73.3)
10-km men	March 4, 2022	09:08:18	28.2 (28.2–30.9)	26.9 (26.9–28.2)	60.2 (48.7–60.2)
20-km women	March 4, 2022	15:58:19	29.1 (27.5–29.3)	25.3 (24.4–25.4)	55.6 (50.4–63.6)
20-km men	March 5, 2022	15:58:19	29.9 (28.2–29.9)	25.7 (24.1–25.7)	52.9 (44.1–61.1)
35-km women/men	March 5, 2022	06:58:19	23.3 (23.3–31.3)	21.5 (21.5–28.6)	79.8 (53.7–79.8)

Abbreviations: RH, relative humidity; WBGT, wet bulb globe temperature.

Statistical Analyses

Statistical analyses were performed using IBM SPSS Statistics for Windows (version 26). Data were descriptively analyzed and presented as mean (SD) or median (interquartile range [IQR]), depending on their parametric nature (assessed via Shapiro–Wilk/Kolmogorov tests and histogram plots), and percentage when possible. Athletes were also grouped according to sex (males vs females) and self-reported climate (athletes who live/train in a hot vs temperate/cold climate) for further comparisons. Relationships between ranking (medalist/top 10 vs nonmedalist/nontop 10) and precompetition use of HA were assessed. One-tailed Mann–Whitney *U* tests were performed to compare scale and ordinal data differences. Binomial and multinomial logistic regressions (with odds ratio [OR], Wald statistic, and 95% confidence interval [CI]) were performed to determine relationships in categorical data. To prevent the violation of collinearity, multinomial logistic regression was run without the intercept. Due to low number of responses in multinomial logistic regression, some levels/categories were excluded or combined to meet the assumptions of the test. When assumptions of independence were not met, cross-tabs were performed for descriptive purposes. Statistical significance was accepted at $P \leq .05$.

Results

Descriptive data are provided within tables and figures. As athletes can select more than one response/option within a question, the number of times an option is selected may be different to the study sample size.

Preparation for the Heat for This World Championship

Heat Adaptation Practice

Athletes reported using either heat acclimatization only (34%; train in a natural hot environment/country), heat acclimation only (19%; train in an artificial hot room), and both HA (5%), and not carrying out specific heat training (43%) in preparation for Muscat (Table 3). One participant was excluded from analysis of this question due to reporting 2 opposing options (ie, "heat acclimatization only" and "no specific heat training"). Athletes who live/train in hot climates were more likely to report using heat acclimatization only (59%) rather than "no specific heat training" compared with athletes from cold/temperate climates (21%; $P = .002$; OR = 8.7; 95% CI, 2%–34%). Heat acclimatization duration reported was predominately for >10 days (72%), where males (88%) were more likely to report acclimatizing for >10 days compared with females (38%; $P = .020$; OR = 0.08; 95% CI, 0.01%–0.68%; Table 3).

Four surveyed athletes were medalists and had specifically prepared for the heat in Muscat (3 athletes [75%] used heat acclimation, with one [25%] heat acclimatization; Table 4). Of all athletes (n = 15) who ranked within the top 10, 80% prepared for the heat prior to the WRW (Table 4). Surveyed athletes who ranked top 10 were more likely to report having prepared for the heat specifically prior to the event, compared with those who did not finish within the top 10 ($P = .049$; OR = 0.25; 95% CI, 0.06%–1%).

Heat Acclimation Strategies

Active heat acclimation was most popular across athletes (87%), of these athletes 62% used self-regulated intensities and 23% used fixed intensities. For athletes who performed heat acclimation (active and/or passive), most athletes used a fixed environmental temperature (93%) instead of using an incremental environmental temperature rise across their protocol (7%). Fixed temperature (31.5 °C [2.7 °C] total) was not influenced by sex (32.4 °C [2.7 °C] males vs 32.2 °C [4.7 °C] females; $P = .470$) or climate (31.5 °C [3.32 °C] hot vs 32.7 °C [3.29 °C] temperate/cold; $P = .927$; Figure 1).

Personal Knowledge and Perceptions of Heat Acclimation/Acclimatization and Related Practices

Expected Conditions in Muscat

Females (42%) were more likely than males to report not knowing the maximum environmental conditions expected (14%; $P = .016$; OR = 4.3; 95% CI, 1%–14%; Table 5). Those who reported knowing stated a mean maximum ambient temperature of 31.9 °C (3.05 °C) and 66.9% (14.45%) humidity, which was not modified by sex (32.3 °C [2.58 °C], 66.1% [14.22%] males vs 30.8 °C [3.91 °C], 68.9% [15.36%] females; all $P \geq .279$–.602) or climate (31.1 °C [3.49 °C], 67.9% [15.33%] hot vs 32.4 °C [2.71 °C], 66.3% [14.10%] temperate/cold; all $P \geq .058$–.673; Figure 2A).

Heat Adaptation Knowledge

Females (83%) were more likely not to know what WBGT is compared with males (55%; $P = .024$; OR = 4.1; 95% CI, 1%–14%;

Table 3 Athlete Preparation for the Environmental Conditions in Muscat

	Sex				Climate					
	Male		Female		Hot		Temperate/ cold		Total	
	n	%	n	%	n	%	n	%	n	%
Heat preparation for this world championship (n = 65)	n = 41		n = 24		n = 22		n = 43			
Acclimatization	14	34.1	8	33.3	13	59.1*	9	20.9*	22	33.8
Acclimation	9	22.0	3	12.5	4	18.2	8	18.6	12	18.5
Both HA	3	7.3	—	—	1	4.5	2	4.7	3	4.6
No specific heat training for Muscat[a]	15	36.6	13	54.2	4	18.2	24	55.8	28	43.1
Acclimatization duration (n = 25)	n = 17		n = 8		n = 15		n = 10			
5 d or less	2	11.8	1	12.5	2	13.3	1	10.0	3	12.0
6–10 d	—	—	4	50.0	3	20.0	1	10.0	4	16.0
More than 10 d[a]	15	88.2**	3	37.5**	10	66.7	8	80.0	18	72.0
Acclimation duration (n = 15)	n = 12		n = 3		n = 5		n = 10			
5 d or less	4	33.3	1	33.3	1	20.0	4	40.0	5	33.3
6–10 d	5	41.7	2	66.7	2	40.0	5	50.0	7	46.7
More than 10 d[a]	3	25.0	—	—	2	40.0	1	10.0	3	20.0
Acclimation methods (n = 5)	n = 3				n = 1		n = 2			
Chamber	3	60.0	—	—	1	50.0	2	66.7	3	60.0
Hot water bath	1	20.0	—	—	—	—	1	33.3	1	20.0
Nonrelevant[b]	1	20.0	—	—	1	50.0	—	—	1	20.0
Acclimation temperature exposure (n = 15)	n = 12		n = 3		n = 5		n = 10			
Fixed temperature	11	91.7	3	100	4	80.0	10	100	14	93.3
Rising temperature	1	8.3	—	—	1	20.0	—	—	1	6.7
Acclimation type (n = 15)	n = 12		n = 3		n = 5		n = 10			
Active acclimation	10	83.3	3	100	3	60.0	10	100	13	86.7
Passive acclimation	1	8.3	—	—	1	20.0	—	—	1	6.7
Both types of acclimation	1	8.3	—	—	1	20.0	—	—	1	6.7
Active acclimation intensity (n = 13)	n = 10		n = 3		n = 3		n = 10			
Fixed intensity	2	20.0	1	33.3	—	—	3	30.0	3	23.1
Self-regulated intensity	6	60.0	2	66.7	2	66.7	6	60.0	8	61.5
Variable intensity for a desired Tc	2	20.0	—	—	1	33.3	1	10.0	2	15.4

Abbreviations: %, percentage of cases in that group/category; HA, heat acclimation/acclimatization; n, number of times option selected; Tc, core temperature. Note: "n" split into sex and climate to determine whether differences exist.
[a]Reference variable. [b]Midday training.
*Statistically significant difference between climate. **Statistically significant difference between sex.

Table 4 Athlete Ranking and HA Use, n (%)

	Medal ranking		Top 10 ranking	
	Yes (n = 4)	No (n = 61)	Yes* (n = 15)	No* (n = 51)
HA[a]	4 (100)	33 (54)	12 (80)	25 (50)*
No HA	0 (0)	28 (46)	3 (20)	25 (50)
Specific HA strategy				
Heat acclimatization	1 (25)	21 (34.4)	4 (26.7)	18 (36)
Heat acclimation	3 (75)	9 (14.8)	6 (40)	6 (12)
Both HA	0	3 (4.9)	2 (13.3)	1 (2)
No HA	0	28 (45.9)	3 (20)	25 (50)

Abbreviations: %, percentage of cases in that group/category; HA, heat acclimation/acclimatization; n, number of times option selected. Note: N = 65.
[a]Reference variable.
*Significant relationship between top 10 ranking and heat preparation.

Table 5). Estimated duration to achieve "full" heat adaptation (14 d, IQR: 10 total) and knowledge of optimal body Tc for active heat acclimation (37.3 °C, IQR: 3.17 total) were not modified by sex (14 d, IQR: 10, 37.7 °C, IQR: 2.50 males vs 15 d, IQR: 11, 37 °C, IQR: 2.65 females; all $P \geq .156$–$.404$) or climate (15 d, IQR: 12, 37.2 °C, IQR: 3.60 hot vs 14 d, IQR: 11, 37.4 °C, IQR: 3.33 temperate/cold; all $P \geq .470$–$.670$; Figure 2B), respectively.

Personal Experience in the Heat, Clinical Background, and History

Athlete Preference and Self-Reported Performance in the Heat

Thirty percent of athletes had a neutral preference toward competing in the heat, 33% reported "disliking training in the heat" followed by "I like" (21%), "I enjoy" (11%), and "I fear" (5%). This was not

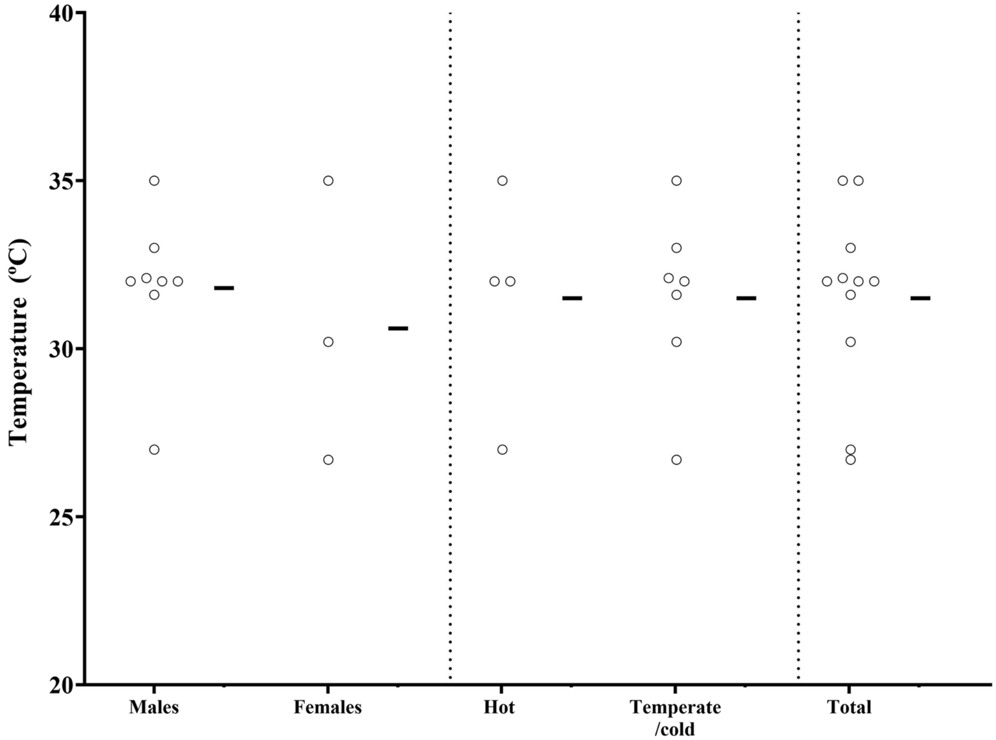

Figure 1 — Reported environmental fixed temperature that athletes were exposed to when acclimating for the heat in preparation for the championships (N = 11). Environmental heat stress (°C) used during heat acclimatization by sex, climate, and total mean and individual responses. Individual responses are represented by ○, and the mean is represented by –. Each athlete's response is presented more than once in this figure (ie, presented within each of the subgroups).

affected (with "neutral" as the reference category) by sex (all $P \geq .203–.746$) or climate (all $P \geq .366–.817$)—Table 6. In comparison with their competitors, 46% of athletes considered themselves good performers, 44% poor performers, and 11% slightly decreased performers in the heat (Table 5), which was also not affected by sex (all P ≥ .538–.683) or climate (all $P \geq .173–.533$).

Previous Heat Illness Symptom/Diagnosis Experience

Athletes most often reported previously experiencing "dehydration" (90%) from heat exposure. 77% of athletes reported no clinical diagnosis of either EHS or heat exhaustion while 20% had been clinically diagnosed with heat exhaustion only. Sex and climate did not affect the likelihood of reporting previous clinical EHS/heat exhaustion diagnosis (Table 6).

Body Tc

Seventy-seven percent of athletes reported never having measured their Tc. Females (8%) were less likely to report having measured their Tc than males (31%) during previous training/competition ($P = .049$; OR = 0.2; 95% CI, 0.04%–1%). 80% of those previously used body Tc measurement reported using ingestible capsules (Table 6).

Medication, Prebiotic, and Probiotic Consumption Before and During the Championships

Eighty-three percent of female athletes surveyed were not using an oral contraceptive, and 67% reported normal and regular menstruation (Table 6). In the 10 days prior to competition, 24% of athletes reported taking medication and 17% reported orally supplementing with prebiotics/probiotics during 30 days prior to competition of whom 55% reported continued supplementation while in Muscat. Sex (all $P \geq .225–.566$) and climate (all $P \geq .234–.999$) did not modify medication/prebiotic/probiotic intake (Table 7).

Barriers to Implement HA Strategies

"Access to facilities/equipment" (42%) was the most commonly reported barrier to HA, despite encountering no barriers being similarly reported (39%). Athletes from hot climates reported not experiencing barriers (50%), followed by "access to facilities" (27%) and "lack of time" (23%), whereas athletes from temperate/cold climates most commonly reported "access to facilities/equipment" (49%), followed by "no barriers" (33%) and "cost" (30%; Figure 3). 83% of athletes were unaware of the World Athletics "Beat the Heat" leaflet (Table 8).

Discussion

Prior to the WRW, 57% of athletes used HA in preparation for competing in the hot conditions that were expected, completing HA protocols of varying duration (ie, short term ~5 d to long term >14 d; Table 3). Athletes who implemented HA strategies were more likely to rank higher than those who did not while the 4 surveyed athletes who medaled all utilized HA prior to the championships. Athletes demonstrated adequate knowledge of expected conditions in Muscat, but there was high variance in responses

Table 5 Athlete Knowledge and Perceptions

	Sex				Climate					
	Male (n = 42)		Female (n = 24)		Hot (n = 23)		Temperate/ cold (n = 43)		Total (N = 66)	
	n	%	n	%	n	%	n	%	n	%
A. Athlete knowledge of expected environmental conditions for Muscat and WBGT										
Maximum environmental conditions in Muscat knowledge										
Yes	36	85.7*	14	58.3*	36	85.7	14	58.3	50	75.8
No	6	14.3	10	41.7	6	14.3	10	41.7	16	24.2
WBGT knowledge										
Yes	19	45.2	4	16.7	7	30.4	16	37.2	23	34.8
No	23	54.8*	20	83.3*	16	69.6	27	62.8	43	65.2
B. Feeling and perceived performance in the heat										
How do you usually feel while training/ competing in the heat?										
I enjoy	6	14.3	1	4.2	4	17.4	3	7.0	7	10.6
I like	9	21.4	5	20.8	4	17.4	10	23.3	14	21.2
Neutral	11	26.2	9	37.5	8	34.8	12	27.9	20	30.3
I dislike	13	31.0	9	37.5	6	26.1	16	37.2	22	33.3
I fear	3	7.1	—	—	1	4.3	2	4.7	3	4.5
When training or competing in the heat, compared to other competitors, do you consider yourself to be?										
Good performer	19	45.2	11	45.8	13	56.5	17	39.5	30	45.5
Slightly decreased performer	5	11.9	2	8.3	2	8.7	5	11.6	7	10.6
Poor performer	18	42.9	11	45.8	8	34.8	21	48.8	29	43.9

Abbreviations: %, percentage of cases in that group/category; n, number of times option selected; WBGT, wet bulb globe temperature. Note: Total N = 66, split into sex and climate to determine whether differences exist. B. Reference: neutral.
*Statistically significant difference between sexes.

for days required to achieve full HA (ie, 14 d[1] [median: 14 d, range: 2–30 d]) and knowledge of the optimal Tc to induce physiological adaptations (ie, ~38.5 °C[30] [median: 37 °C range: 27–42 °C]). Climate differences existed for heat acclimatization preparation only, and sex differences existed for the following: (1) previous use of Tc measurement during training and competition, (2) knowledge of the expected environmental conditions in Muscat, (3) WBGT knowledge, and (4) acclimatization duration.

Preparation for, Knowledge of, and Perceptions of Competing in the Heat

Despite hot conditions being expected in Muscat for the WRW, 43% of the athletes reported that they did not take part in specific heat training for these championships. Recently, an increase in HA use by elite athletes from the IAAF World Athletics Championships 2015 (15%)[13] to Doha 2019 (63%)[6] has been seen, yet the present data do not continue this increase (57%). However, prior to Doha 2019 (which was pre-COVID pandemic) with a lens toward Tokyo 2020ne, significant attention to the championships being held in extreme temperatures was seen within the sport science/ medicine community and global media.[23] Indeed, pre-Doha 2019 the IAAF (now World Athletics) released "Beat the Heat" educational material to the athletes/federations, likely enhancing uptake of HA protocols for these championships. However, 83% of the athletes (Table 8) at the WRW were not aware of this educational material, a factor that may partially explain the lower use of HA at these championships compared to Doha 2019.[6] Furthermore, while heat was expected in Muscat, it was not expected to be as extreme as Doha 2019 (event start range: Doha 2019: 29–32 °C; 51%–77%; WBGT 23–32 °C; Muscat 2022 expected: 22–30 °C; actual: 23–31 °C; WBGT: 23–30 °C). Therefore, athletes and their teams may not have prioritized HA in the lead up to these WRW championships in the same way as Doha. The importance and benefit of HA prior to competition are highlighted in the present study, surveyed athletes who medaled all adopted HA, and those who ranked in the top 10 were more likely to have implemented HA prior to the championships than those outside the top 10 (Table 4). Similarly, at Doha 2019, athletes who HA ranked higher and were less likely to visit the medical tent.[6] While 82% of athletes who train/live in hot climates did complete a HA protocol (Table 3), access to facilities/ equipment was still the most common barrier to implementing HA reported prior to these championships (in total 42%), similar to previous elite cohorts surveyed.[19] However, these barriers (49%) together with cost (30%) were more commonly reported by athletes from temperate/cold climates, likely accounting, at least in part, for the reduced use of HA among this cohort. It is important to note that the samples were different compared to the previous Doha 2019 study,[6,22] which was open to all road-race athletes, as opposed to the current sample which was exclusively racewalkers.

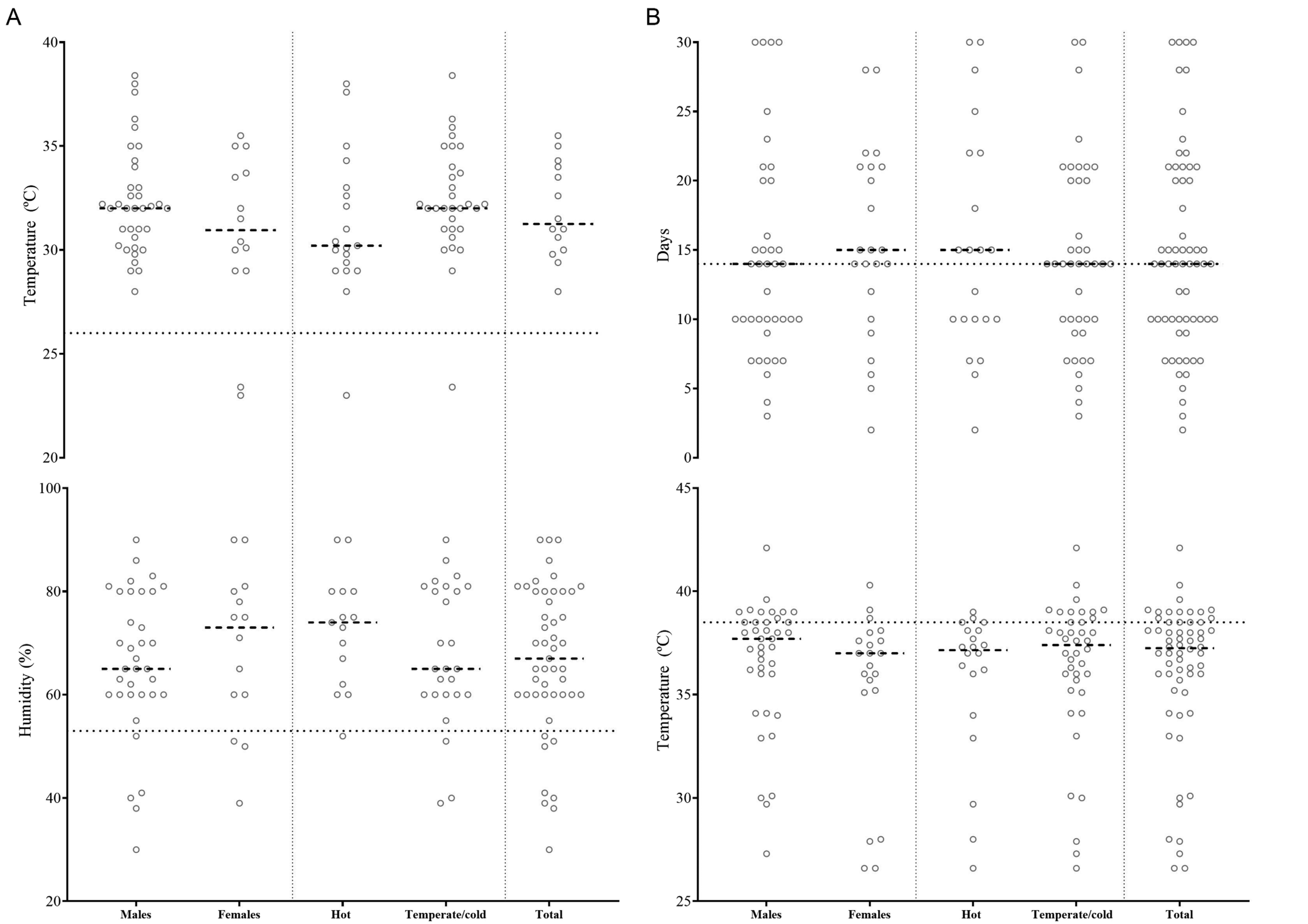

Figure 2 — (A) Perceived maximum environmental temperature (n = 50) and humidity (n = 49) expected for Muscat during the championship. Sex, climate, and total mean and individual responses for the maximum temperature (°C) and maximum humidity (%) reported by athletes. Black dotted lines indicate the historical average maximum temperature for March 4–5 (26 °C) and the monthly average humidity (53%). (B) Perceived number of days to achieve full acclimation duration (n = 62) and perceived Tc (n = 60) considered optimal for active heat acclimation. Sex, climate, and total median and individual responses to days needed for full acclimation and for the optimal Tc (°C) reported by athletes. Black dotted lines indicate current recommendations for full acclimation duration (long-term heat acclimation ≥14 d)[1] and optimal Tc for active heat acclimation (≥38.5 °C).[30] Tc indicates core body temperature.

Table 6 History of Heat Illness, Clinical Diagnosis, and Use of Core Temperature Measurements

	Sex				Climate					
	Male (n = 42)		Female (n = 24)		Hot (n = 23)		Temperate/cold (n = 43)		Total	
	n	%	n	%	n	%	n	%	n	%
A. Reported heat illness symptoms and clinical diagnosis history										
Have you ever experienced the following while training/competing in the heat? (n = 49)										
Cramping	11	33.3	2	12.5	3	8.3	10	13.9	13	26.5
Nausea	9	27.3	9	56.3	5	13.9	13	18.1	18	36.7
Vomiting	11	33.3	6	37.5	6	16.7	11	15.3	17	34.7
Severe headache	5	15.2	6	37.5	4	11.1	7	9.7	11	22.4
Dehydration	30	90.9	14	87.5	16	44.4	28	38.9	44	89.8
Collapsing—Fainting	1	3.0	4	25.0	2	5.6	3	4.2	5	10.2
Have you ever been clinically diagnosed with heat exhaustion or exertional heat stroke? (n = 66)										
Heat exhaustion only	10	23.8	3	12.5	7	30.4	6	14	13	19.7
Exertional heat stroke only	1	2.4	—	—	1	4.3	—	—	1	1.5
Both	—	—	1	4.2	1	4.3	—	—	1	1.5
No	31	73.8	20	83.3	14	60.9	37	86.0	51	77.3
B. Reported previous use of core body temperature measurement and type.										
Have you ever measured your body Tc during training or competition? (n = 66)										
Yes	13	31.0*	2	8.3*	4	17.4	11	25.6	15	22.7
No	29	69.0	22	91.7	19	82.6	32	74.4	51	77.3
If yes, how did you measure it? (n = 15)	n = 13		n = 2		n = 4		n = 11			
Tympanic (ear)	2	15.4	2	50	1	16.7	3	18.8	4	26.7
Rectal	5	38.5	—	—	2	33.3	3	18.8	5	33.3
Oral	1	7.7	—	—	—	—	1	6.3	1	6.7
Ingestible capsule	10	76.9	2	50	3	50.0	9	56.3	12	80

Abbreviations: %, percentage of cases in that group/category; n, number of times option selected. Note: "n" split into sex and climate to determine whether differences exist. Responses may exceed the total number of participants as one participant may report more than one option. Temporal (forehead) and axillary (armpit) were not selected.
*Statistically significant difference between sexes.

The difference in perceived "prestige" of events could also influence the priority given to preparation, potentially explaining differences described above, in athletes' HA practice. Finally, the current survey did not account for any interruptions to preparations due to COVID-19 that may have influenced athletes' use of HA, for example, reducing opportunities to travel to hot locations for training. Likely, a combination of all the above factors contributed to the lower use of a HA protocol prior to the WRW compared to Doha 2019.

Seventy-six percent of athletes reported knowing the environmental conditions for the championships, with females (42% compared with 14% males) more likely to report that they did not know the maximum anticipated environmental conditions in Muscat for the championships (ie, average historical temperatures; Table 5). There was poor knowledge of WBGT (65%; Table 5) among athletes overall, significantly more so in females (83% vs 55% males). Some athletes showed adequate knowledge of time to achieve full HA (ie, 14 d[1]), and even though males were more likely to report heat acclimatizing for more than 10 days (88% vs 38% females), the majority of overall athletes did so for more than 10 days (72%), indicative of medium- to long-term (≥14 d) HA. There was, however, high variance in knowledge regarding responses given for full HA duration (2–30 d; Figure 2), as seen elsewhere.[19] It is important to highlight that not all questions were analyzed for sex and climate differences due to the nature/style of some questions. Historically, maximum environmental temperature in Oman in early March is 26 to 27 °C. It is recommended during HA that athletes prepare in conditions similar to those expected "at worst" historically at the competition venue.[31] Athletes who implemented a HA strategy prior to the championships did so in environmental temperatures that were similar to what they expected conditions to be in Muscat, and although most athletes overestimated the expected conditions in Muscat, this suggests some athletes had knowledge of appropriate HA strategies (Figures 1 and 2). However, athletes underestimated the optimal Tc required to induce the physiological adaptations from a HA protocol (ie, ~38.5 °C[30]) including answers that are biologically implausible (mean: 37 °C; range: 27–42 °C).

Table 7 Recent Illness, Medication, and Supplement Use and Women's Health

	Sex				Climate				Total (N = 64)	
	Male		Female		Hot		Temperate/cold			
	n	%	n	%	n	%	n	%	n	%
A. Recent illness experienced and medication/supplement intake 10 and 30 d prior and during the Championships										
10 d prior competition—Symptoms experienced (n = 64)	n = 40		n = 24		n = 22		n = 42			
Stomach pain	4	10	7	29.2	4	18.2	7	16.7	11	17.2
Insomnia	4	10	6	25	5	22.7	5	11.9	10	15.6
Diarrhea	1	2.5	2	6.5	2	9.1	1	2.4	3	4.7
Vomiting	3	7.5	2	8.3	4	18.2	1	2.4	5	7.8
No illness	33	82.5	14	58.3	14	63.6	33	78.6	47	73.4
10 d prior competition—Medication intake (n = 66)	n = 42		n = 24		n = 23		n = 43			
Yes	8	19	8	33.3	4	17.4	12	27.9	16	24.2
No	34	21	16	66.7	19	82.6	31	72.1	50	75.8
30 d prior competition—Prebiotic/probiotic supplementation (n = 66)	n = 42		n = 24		n = 23		n = 43			
Yes	6	14.3	5	20.8	2	8.7	9	20.9	11	16.7
No	36	85.7	19	79.2	21	91.3	34	79.1	55	83.3
While in Muscat—Prebiotic/probiotic supplementation (n = 11)	n = 6		n = 5		n = 2		n = 9			
Yes	2	33.3	4	80	—	—	6	66.7	6	54.5
No	4	66.7	1	20	2	100	3	33.3	5	45.5
			n	%						
B. Women's health (n = 24)										
Use of oral contraceptive pill										
Yes			4	16.7						
No			20	83.3						
Normal and regular menstruation										
Yes			16	66.7						
No			8	33.3						

Abbreviations: %, percentage of cases in that group/category; n, number of times option selected. Note: "n" split into sex and climate to determine whether differences exist. Responses may exceed the total number of participants as each participant may have reported more than one option.

The data from this sample identify that elite racewalkers have variable knowledge of best practice in preparation for competing in hot conditions, similar to previous data from elite athletes across a wider spectrum of sports.[19] Endurance athletes are at greatest risk of EHI/S given their exposure to prolonged time spent at high Tc.[32] Therefore, bridging the gap between research and evidence-informed best practice regarding HA in elite sport should remain a priority. Indeed, a recent call has been made to improve educational resources and the translation of knowledge to practice.[19] The fact that 83% of the current athlete cohort were not aware of the "Beat the Heat" information provided by World Athletics is clear evidence of this need (perhaps the positive effects of such educational initiatives are relatively short-lived and require a consistent and continually invigorated presence). Furthermore, these data suggest that further efforts are required to reach elite female athletes given unfavorable sex-based knowledge discrepancies in heat-related practice.

As global temperatures increase,[21] understanding athlete responses to hot environments is likely to become paramount for health and performance. Measuring Tc is best practice and key to assessing athlete response to heat, diagnosing EHI/S[9] (eg, confirmed hyperthermia and rectal temperature ≥40.5 °C), and monitoring athlete's recovery from EHI/S symptoms/diagnosis.[25] With 77% of the current cohort of athletes having never measured Tc, this further highlights the disconnect between knowledge and best practice, albeit at a slightly lower percentage compared with previous research (86%).[19] Tc monitoring can now be achieved noninvasively via ingestible telemetric pills and can easily be assessed in training and competition[6,8,22]; however, this technology is not cheap and may only be available to well-funded federations/athletes.

Typically, endurance athletes have negative associations between hot-humid environments and their athletic performance.[19] However, in the present study racewalkers' perception of the impact of heat on their performance was less negative in comparison to previous cohorts surveyed (inclusive of team sports, triathletes, tennis and so on) who generally overestimated the perceived versus real impact of heat on performance[19] (Table 5). Even though it is not possible to ascertain whether these perceptions influenced athletes' decisions to HA, or not, prior to the WRW, these data suggest that athletes may not always dislike exercising in hot conditions.

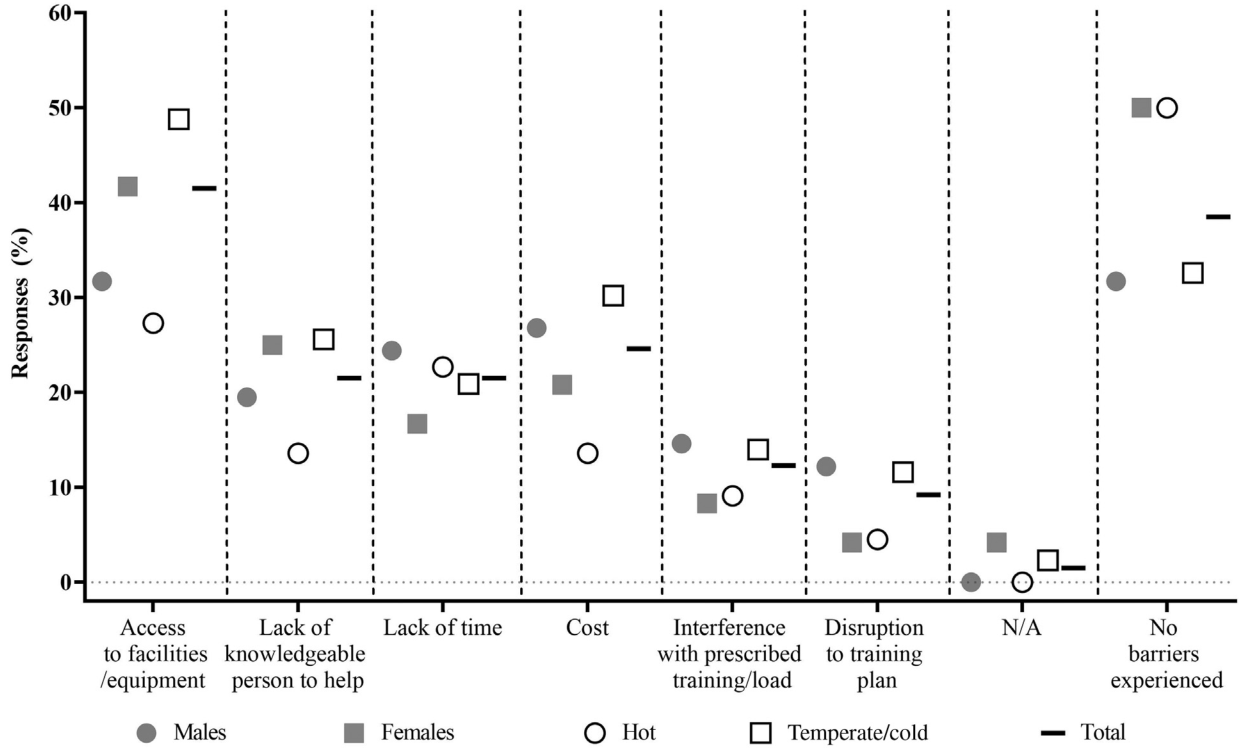

Figure 3 — Mean percentage (%) of reported barriers encountered by athletes (N = 65) when implementing heat acclimation strategies. Gray dotted line represents 0 across the figure.

Table 8 Awareness of "Beat the Heat" Leaflet on Heat Illness Prevention Produced by World Athletics

	Sex				Climate					
	Male		Female		Hot		Temperate/cold		Total	
	n	%	n	%	n	%	n	%	n	%
"Do you know about the leaflet?" (n = 65)	n = 41		n = 24		n = 22		n = 43			
Yes	9	22.0	2	8.3	3	13.6	8	18.6	11	16.9
No	32	78.0	22	91.7	19	86.4	35	81.4	54	83.1
If Yes, "Have you read it?" (n = 11)	n = 9		n = 2		n = 3		n = 8			
Yes	7	77.8	1	50.0	2	66.7	6	75.0	8	72.7
No	2	22.2	1	50.0	1	33.3	2	25.0	3	27.3
If No, "Would you like an electronic version" (n = 54)	n = 32		n = 22		n = 19		n = 35			
Yes	25	78.1	15	68.2	17	89.5	23	65.7	40	74.1
No	7	21.9	7	31.8	2	10.5	12	34.3	14	25.9

Abbreviations: %, percentage of cases in that group/category; n, number of times option selected. Note: "n" split into sex and climate to determine whether differences exist.

Strengths and Limitations

This study offers insight into racewalkers' practice, preparedness, and health prior to an elite World Championship event in hot conditions. While a small sample size, such a homogenous sample is representative of this unique sport and similar response rates have been regarded as acceptable in the literature.[13] In addition, this sample includes 16 different nationalities from hot and temperate climates, and it should be noted that climate of origin was self-reported and not objectively quantified (ie, temperature cutoffs). The survey regrettably did not determine how COVID may have influenced the athletes' practices (eg, HA); however, it covered important aspects of preparation, knowledge, and health in elite athletes at the time of the WRW. The sample characteristics precluded associations and differences by athlete nationality, country of residence, or GDP (gross domestic product) (this could be interesting given one would assume athletes within a federation are provided with the same resources/training regimen/education). Finally, participants' self-reporting poses a certain risk of response bias.

Practical Applications

1. Athletes who HA tended to rank higher than those who did not, further highlighting the importance/need for HA to be implemented prior to competition in the heat.
2. Access to facilities and cost are barriers to the use of HA, persisting among athletes especially in those who live/train in cold/temperate climates, regardless of recent evidence supporting cost- and time-effective strategies not solely reliant on classical heat chambers or warm weather (eg, passive heat exposure and added thermal clothing).[17]
3. While accessible educational resources (ie, "Beat the Heat" leaflets) have been developed by World Athletics, these do not seem to have exerted a sustained positive effect versus their initial evidenced success—renewing and improving education among athletes by increasing the awareness of these resources is important.

Conclusions

This study shows the importance of heat acclimation/acclimatization (HA) to performance in the heat with surveyed athletes who implemented an HA strategy prior to the World Athletics Race Walking Teams Championships (WRW) tending to rank higher than those who did not. There was a slight decline in HA use prior to the WRW compared with the Doha 2019 Championships, potentially attributable to the following: (1) variable knowledge of best practice and/or differences in perceptions of exercise and performance in the heat, (2) barriers to HA like access to facilities and cost, and (3) perceived event priority. Sex differences in knowledge, as well as sex and climate differences in specific HA practice, suggest further efforts to reach elite female athletes and athletes from cold/temperate climates are required. This study reiterates previous survey-based data calling for improved educational resources and translation of knowledge to practice in order to bridge the gap between research and the implementation of well-evidenced best practice related to hot-humid environments in elite sport.

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