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CURRENT OPINION

From Lab to Real World: Heat Acclimation Considerations for Elite Athletes

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Abstract As major sporting events are often held in hot environments, increased interest in ways of optimally heat acclimating athletes to maximise performance has emerged. Heat acclimation involves repeated exercise sessions in hot conditions that induce physiological and thermoregulatory adaptations that attenuate heat-induced performance impairments. Current evidence-based guidelines for heat acclimation are clear, but the application of these recommendations is not always aligned with the time commitments and training priorities of elite athletes. Alternative forms of heat acclimation investigated include hot water immersion and sauna bathing, yet uncertainty remains around the efficacy of these methods for reducing heat-induced performance impairments, as well as how this form of heat stress may add to an athlete's overall training load. An understanding of how to optimally prescribe and periodise heat acclimation based on the performance determinants of a given event is limited, as is knowledge of how heat acclimation may affect the quality of concurrent training sessions. Finally, differences in individual athlete responses to heat acclimation need to be considered. This article addresses alternative methods of heat acclimation and heat exposure, explores gaps in literature around understanding the real world application of heat acclimation for athletes, and highlights specific athlete considerations for practitioners.

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Key Points

Post-exercise sauna bathing and/or hot water immersion may represent a practical means of implementing heat acclimation (HA) in athletes when barriers to traditional exercise-based HA are present.

To optimise HA, the timing of implementation, sport specificity and other concurrent training sessions should all be considered in order to maintain training quality and maximise performance in the heat.

Several unique athlete considerations, including their history and physical characteristics, should be understood by practitioners before implementing HA protocols, as individual characteristics often elicit different heat stress and HA responses.

1 Introduction

Several major sporting events are held each year in hot environments. Some of the largest high profile events, including most Summer Olympic Games, the Tour de France, the FIFA World Cup, as well as several annual World Cups and World Championships are held in the summer months when high temperatures are often expected. For athletes and support teams preparing for pinnacle events, executing performance to their maximum potential is of the utmost importance. Heat-induced performance decrements can range from 6 to 16% in trained athletes during endurance and team sport events [1–3], while lack of acclimation is a major risk factor for exertional heat injury (EHI) [4]. Heat acclimation (HA) or acclimatisation involves repeated exercise sessions in hot conditions (typically ~30–40 °C, 20–60% relative humidity (RH) for athletic circumstances) either by artificial means (acclimation; heated room or chamber) or outdoors (acclimatisation; hot ambient temperature), and is a routine strategy employed to induce physiological adaptations that will attenuate heat-induced performance impairments and offer protection against heat stress and EHI [5–7]. Recent consensus recommendations offer practitioners an understanding of the key concepts needed to prescribe HA for individual and team sport athletes [8, 9]. Briefly, these best practice guidelines state that HA should be comprised of daily ~60 min training sessions in hot conditions for a minimum of 1 week, and ideally over 2 weeks to achieve further thermoregulatory and performance benefits. The HA protocol should mimic the event demands while inducing high sweat rates and increased body (skin and core) temperature [9].

A number of scenarios have been proposed in the literature to administer HA within an athlete's season to maximise performance in hot conditions, including pre- or in-season training camps to augment the training response, or as a taper tool when training volume is reduced and high-intensity quality is to be maintained [8, 9]. While such recommendations are based on decades of evidence, limitations and barriers to adhering to such guidelines, within the context of elite athlete training needs, pose frequent conundrums for coaches and sport scientists. In short, best practice guidelines are often not entirely attainable within the confines of highly demanding physical preparation and travel, which are necessary requirements for the elite athlete. The purpose of this current opinion piece, therefore, is to review alternative methods of HA and heat exposure, explore the gaps in literature for understanding how HA might be integrated into an athlete's existing training program, and highlight specific athlete considerations for practitioners.

2 Alternative Heat Acclimation (HA) Methods

Sport-specific HA, simulating competition-like conditions, is now considered best practice HA for athletes [9]. Unfortunately, several barriers may prevent athletes from achieving HA in this way, especially for those athletes living in cold-to-temperate climates. HA protocol design challenges may include limited access to environmental chambers, constrained training modes not attainable within the small confines of most environmental chambers, high costs associated with international travel to conduct heat camps, and potential interference that HA may have with higher-prioritised training phase objectives. Alluring alternative HA strategies for athletes, such as post-exercise hot water immersion and sauna bathing, have been shown to elicit the desired physiological adaptations [10, 11], while overcoming the aforementioned barriers that traditional HA present. These HA alternatives and their reported effects are summarised in Table 1 and described briefly below.

2.1 Hot Water Immersion

Hot water immersion applied in untrained men as a form of passive HA has been shown to enhance thermoregulation [12–14] and improve exercise performance in the heat [11]. In one study, seven 45-min hot water baths (44 °C) completed over a 2-week period were shown to reduce thermal and cardiovascular strain, through reductions in core temperature (0.30 °C) and heart rate (12 beats/min (bpm)) [13]; an effect comparable to what is typically shown after conventional short-term HA [15]. Likewise, Zurawlew et al. [11] showed reductions in both resting (0.27 °C) and end-exercise (0.28 °C) core temperature, as well as a 4.9% improvement in 5-km run time trial (TT) performance in hot conditions (33 °C) following six consecutive post-exercise hot water baths (40 min running at 65% maximal oxygen consumption ($\dot{V}O_{2max}$) in 18 °C; 40 min bath in 40 °C water). This performance improvement seems meaningful given that the coefficient of variation (CV) for a 5-km TT performance is 2% [16]. Given many training facilities have hot baths available to athletes for hydrotherapy purposes, hot water immersion holds potential as an accessible and time-efficient means of inducing HA. Further research with trained individuals is needed to understand the effects of hot water immersion compared with best practice HA methods.

2.2 Post-Exercise Sauna

The high thermal load (80–100 °C, 10–20% RH) imposed by sauna bathing presents its use as a potentially practical HA approach. Sauna bathing in a rested state has been shown to impose considerable heat stress, resulting in increased core and skin temperature, sweat rate and heart rate [17]. Consecutive days of sauna bathing in healthy untrained men has been shown to increase heat tolerance after only 3-day exposures, as evidenced by reductions in core temperature [18]. Sauna exposure immediately following a training session may enhance the thermoregulatory-adaptive response, as core temperature, considered a key contributor to HA-induced adaptations [19], has been shown to rise to a greater extent compared with sauna bathing without exercise [20]. Furthermore, post-exercise heat stress may additively enhance endurance training-induced mitochondrial function through increased citrate synthase enzyme activity [21]. To date, only two studies have reported on the use of post-exercise sauna

Table 1 Passive heat acclimation strategies using hot water immersion (HWI) and post-exercise sauna bathing (PES)

Study	Participants	Intervention	Protocol	Conditions	Physiological responses	Performance test
Bonner et al. [12]	$n = 5$ Male; untrained	HWI (whole body)	13 × 60 min controlled hyperthermic HWI	HWI ~41 °C; $T_a = 40$ °C	↓ T_c, ↓ HR, ↑ sweat rate, ↑ PV (6.7%)	None
Brazaitis et al. [13]	(Exp) $n = 13$; (Con) $n = 12$ Female and male; untrained	HWI (lower limb)	7 × 45 min HWI sessions over 2 week; alternate days	HWI ~44 °C; $T_a = 23$ °C	0.30 °C ↓ T_c, 12 bpm ↓ HR, 0.3 L·h^{-1} ↑ sweat rate, 1.0 AU ↓ PSI	↓ Central and peripheral fatigue w/hyperthermia; no Δ post HA
Shin et al. [14]	$n = 9$ Male; untrained	HWI (lower limb)	10 x 30 min HWI sessions over 3 week; alternate days	HWI ~42 °C; $T_a = 26$ °C	0.13 °C ↓ T_c, 0.2 L·h^{-1} ↑ sweat rate	None
Zurawlew et al. [11]	(Exp) $n = 10$; (Con) $n = 7$ Male; active	HWI (whole body)	6 x 40 min HWI sessions over 3 week; randomised between-subjects control trial	~40 °C	0.36 °C ↓ T_c, 6 bpm ↓ HR, ↔ sweat rate, 0.5 AU ↓ PSI	4.9% ↓ 5-km TT in 33 °C
Scoon et al. [10]	$n = 6$ Male; mod-trained	PES	~13 x 30 min PES sessions over 3 week; randomised crossover control trial	~90 °C	7.1% ↑ PV, unclear 3.5% ↑ RCV	32% ↑ TTE (~2% ↓ 5-km TT)
Stanley et al. [22]	$n = 7$ Male; well-trained	PES	10 x 30 min PES sessions; consecutive days	87 °C 11% RH	17.8% ↑ PV, 15.6% ↓ HRR_{60s}	None reported

All reported increases (↑) or decreases (↓) were significant changes

AU Arbitrary unit, *Con* control group, *Exp* experimental group, *HA* heat acclimation, *HR* heart rate, HRR_{60s} heart rate recovery at 60 s, *mod* moderately, *HWI* hot water immerson, *PES* post-exercise sauna, *PSI* physiological strain index, *PV* plasma volume, *RCV* red cell volume, *RH* relative humidity, T_a ambient temperature, T_c core temperature, T_{sk} skin temperature, *TT* time trial

bathing in trained athletes; however, neither study examined the typical spectrum of HA-induced adaptations [10, 22]. Both studies used ~10–15 post-exercise sauna sessions and reported significant plasma volume expansion (7–17%) [10, 22]. Only one study showed a possible improvement in running performance, equivalent to a ~2% improvement in 5-km TT performance in temperate conditions [10], and equal to the performance test CV [16]. Similar to hot water immersion, post-exercise sauna bathing may be more accessible than heat chambers for some athletes, and can be conveniently added to a training schedule with minimal disruption. While post-exercise sauna bathing is currently recommended by specialists as an HA alternative [9], no studies have reported its efficacy to induce thermoregulatory adaptations and enhance performance in hot conditions.

3 Integration with Training

3.1 Prescription and Periodization

The majority of HA-induced adaptations (reduced body temperature, cardiovascular strain, perceived effort and discomfort) are actualised following short-term HA (4–7 days) [23], with further thermoregulatory (increased sweat rate) [24] and exercise capacity enhancement [25] requiring moderate-term HA (8–14 days) or even long-term HA (≥15 days). Long-term HA, though often overlooked as an HA strategy for athletes, may have merit for athletes preparing to perform ultra-endurance events in the heat, as longer-term HA has been shown to enhance molecular and cellular adaptations leading to improved cardiac contractile efficiency during exercise in the heat, and a greater accumulation of heat shock proteins, albeit in untrained animal models [26]. Direct comparisons of differing HA intervention length on performance outcomes would aid the development of HA dose recommendations based on competition length, thus providing an evidence-based menu that practitioners could refer to. For instance, long-term HA may be more optimal for endurance events over 2 h, where larger heat performance decrements are often evident (~3%) compared with middle-distance events (1%) [25], in which short- to moderate-term HA may be sufficient.

The appeal and ease of implementing short-term HA within an athlete's training schedule has driven research to determine the minimal dose of HA required to elicit thermal adaptations and enhance performance in the heat.

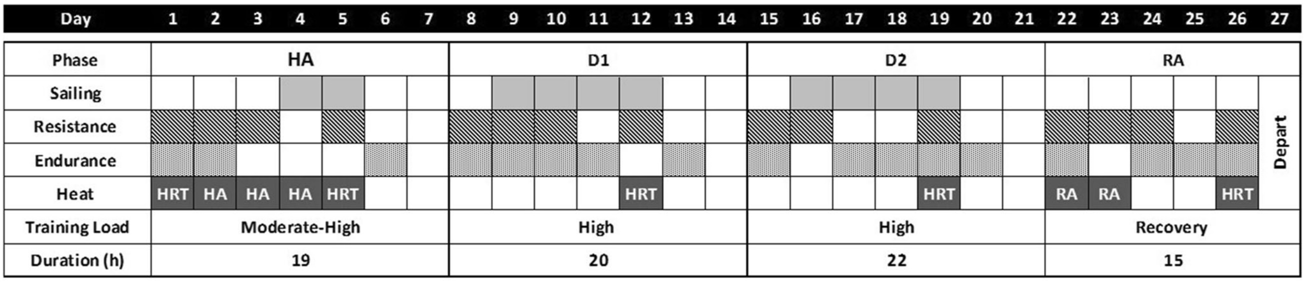

Fig. 1 Overview of the periodised heat acclimation (HA) protocol used for two elite Laser sailors preparing for the world championships in Oman. A 4-week mesocycle included three heavy-build weeks and one recovery week (TSS = training stress score). HA [35 °C, 65% relative humidity (RH)] occurred during the first week with a heat response test (HRT) on day 1 and day 5 of HA. HRTs were repeated during the two following weeks of decay, and 3 days post re-acclimation (RA). Reproduced from Casadio et al. [35], with permission

Rapid HA with just 2 days of twice-daily HA was recently shown to improve 3-km TT running performance (3.5%) in hot conditions (30 °C, 60% RH) in moderately-trained males [27]. Five sessions of short-duration (27 min) high-intensity intermittent HA, over a 9-day normal training period, in Australian Rules Football players reduced RPE, thermal discomfort and blood lactate during a submaximal heat stress test in hot conditions (~ 38 °C, 30% RH) [28]. Core temperature, sweat rate and heart rate were unaffected by these low-volume short-term HA protocols, supporting the notion that HA strategies should include a minimal duration at which an athlete's core temperature is elevated [29]. However, caution is warranted when attempting 'rapid' short-term HA strategies, as the protective effects (reduced core temperature and heart rate; increased sweat rate) that longer-term HA elicit appear to be lacking, and therefore these strategies may not sufficiently eliminate heat-induced performance impairments nor reduce an athlete's risk of EHI [4, 25].

The periodisation of HA poses complex questions around how best to schedule HA into an athlete's training and competition calendar, where multiple events held in hot environments are likely throughout a competitive season. While more evidence is needed around its application in highly-trained populations, current literature has shown that adaptations following HA appear to decay after 2–4 weeks depending on HA length [30], while re-acclimation may occur with fewer sessions [31, 32]. As highly-trained individuals may have slower rates of HA decay [33], and because periodic exposure to heat following HA can allow for the retention of HA over several weeks [34], it may be worth periodising HA intermittently throughout a competitive season. Furthermore, a 'thermal memory' or 'thermal plasticity' concept may exist, where rapid re-acclimation is possible in those who have used HA routinely [19]. These concepts were recently applied in a case study where HA decay was perhaps lessened following 2 weeks of HA in an elite sailor [35]. Indeed, 2 days of consecutive re-acclimation provided further thermoregulatory enhancement [35], and is supported by similar findings in occupational settings [31, 32]. Figure 1 offers an example of how HA might be implemented in the build-up phase for athletes departing for a competition in hot conditions. Introducing HA 2–3 weeks prior to travel, combined with re-acclimation sessions before departure, poses an attractive strategy to 'top up' heat tolerance adaptations following a period of HA decay, and may alleviate training disruptions caused by repeating subsequent HA periods. More work is needed to understand how to optimise the periodisation of HA within an athlete's annual training plan.

3.2 Concurrent Training Considerations

The training programme structure of an elite athlete is often complex and multifaceted, with multiple layers of stress applied at various times, altogether aiming to develop the physical and mental resiliency needed for peak performance. When heat stress is added to training, coaches and sport scientists must consider the impact that HA will have on the athlete's overall state of stress. For example, heat stress on top of normal training stress is likely to impact upon an athlete's overall sympathovagal balance [36–39] and resulting hypothalamic-pituitary-adrenal axis response [40]. While recommendations have been made to adjust overall training intensity, volume and recovery practices during periods of HA [25], detail is lacking on exactly how practitioners should do so. Horowitz [19] explains that heat stress is a potent stimulus affecting every cell of the body, translating to heat-induced augmentations in sympathetic nervous system activity [41], cardiac strain [42] and rate of fuel utilisation [43, 44], thus resulting in an increased energy cost for a given exercise intensity [45]. Such added stress has been shown to not only amplify internal training load [46], but could potentially impair an athlete's ability to recover for subsequent training sessions [47]. This scenario provokes questions as to how concurrent training should be structured around HA, which sessions heat should be added to, and how subsequent routine training sessions should be adjusted based on prior heat stress.

It seems logical to use sport-specific exercise modes for HA sessions that provide opportunities for athletes to simulate competition in hot conditions to fine tune pacing and cooling strategies prior to competition [48]. However, a number of authors speculate that low- to moderate-intensity sessions may be performed best in the heat during HA periods, and that so-called 'key' training sessions of higher-intensity might be performed in cool conditions, to avoid reduced training quality that could potentially lead to a diminished high-intensity stimulus and associated peripheral adaptations over an extended HA period [25, 48]. Conversely, key sessions may warrant their place in the heat chamber in sports where there is an anaerobic or power component. For example, a recent comparison of low- [90 min at 40% maximal aerobic power output (P_{max})] versus high-intensity (5 × 3 min at 70% P_{max}, 3 min at 30% P_{max}) HA resulted in performance enhancement that was somewhat specific to the type of HA undertaken [49]. Specifically, low-intensity HA resulted in improved 20-km TT endurance performance (5.9%), while high-intensity HA showed improvements in anaerobic performance (early sprint peak power output, vertical jump, counter-movement jump), without performance changes in the 20-km TT [49]. As with normal variations in training intensity, perhaps a combination of high- and low-to-moderate-intensity training in the heat would elicit a wider range of performance benefits in the heat for sports with multiple performance determinants. In addition, introducing high-intensity HA sessions may be best placed following 2–3 days of HA once initial adaptations to the heat have occurred, thus supporting the maintenance of intensity in hot conditions.

Athletes undergoing HA could be training up to 2–3 times per day, yet an understanding of how previous and subsequent routine training sessions surrounding HA may affect an athlete's response is largely unexplored and possibly overlooked by practitioners. Exercise-induced muscle damage, through high-volume eccentric training, has been shown to increase core temperature (0.2–0.3 °C) during a subsequent exercise bout and may be explained by an augmented inflammatory response [50, 51]. However, this eccentric training-induced increase in heat strain is diminished with repeated bouts of eccentric training (repeated bout effect) [52]. Practically speaking, if eccentric training is introduced during a period of HA, heat strain may be elevated during the initial days. Interestingly, heat strain itself imparts a prophylactic effect against muscle damage [53], so it might be used as a tool in endurance athletes, i.e. heat applied in the period before introduction to eccentric resistance training to reduce muscle soreness. In addition, low-intensity short-term HA (5 days; 90 min of cycling at 40% of power) has been shown to reduce mean and peak torque during a maximal voluntary contraction [49]. This finding supports the concept that endurance-based HA might impair training quality and adaptive responses during routine concurrent resistance training. In contrast, some have shown that applying heat to skeletal muscle, with or without resistance training, can augment maximal force and muscle cross-sectional area over a 10-week period in untrained men [54, 55]. Mechanistic studies have shown that heat stimulates the Akt/mammalian target of rapamycin (mTOR) signalling pathway, a key regulator of protein synthesis and hypertrophy [56, 57]. Thus heat, applied in various ways, could provide an ergogenic effect when combined with resistance training. In summary, practitioners should consider the effects of HA on concurrent resistance training sessions. Introducing eccentric training during a period of HA should be avoided when the maintenance of a specific heat strain level during HA is required. Long-duration endurance sessions in the heat may impair the quality of concurrent resistance training. Finally, heat may be used as a training tool to incur protection against muscle damage or to augment muscle strength and hypertrophy adaptations.

4 Athlete Considerations

As no two athletes are the same, the high variation in individual responses to training [58–60] and environmental stress [3, 61] is unsurprising. Understanding how each athlete responds to added heat stress and acclimation through repeat heat response testing is therefore key and should be conducted well before any critical event in hot conditions [3, 62]. Heat response tests can be sport-specific, be comprised of a steady-state effort, and/or include a performance measure. The protocol should complement normal training so it can be easily repeated, possibly multiple times a season, to assess an athlete's level of acclimation. Simple measures, such as heart rate, sweat rate, thermal perception and rating of perceived exertion can be easily employed without specialised equipment, while core temperature and plasma volume (or at least their change) can add further valuable information if available. High inter-individual variability in responses to heat response testing can be expected, even within similar athlete cohorts, which may be explained by several factors, summarised in Table 2. These include sex differences [24, 63, 64], differences in ethnicity [6, 65–68], athlete type [69], training status [33, 70–72], anthropometric characteristics [73–77], previous HA [31–33, 35], history of EHI [78, 79], and sleep quality and duration [78]. For female athletes, thermoregulatory changes due to menstrual cycle phase [80–83] and oral contraceptive use [84–86] could cause false-negative or -positive responses to heat response testing following HA, and should be noted prior to any thermoregulatory assessment. In addition, practitioners working with female athletes should consider that HA induction may require moderate-term HA [81, 87], as short-term HA may be less effective in females [88] compared with males [24]. Paralympic athletes require special considerations when training and competing in the heat, especially those with spinal cord injuries whose sudomotor cooling capacity is limited [89–91]. Finally, there is merit in discerning the immune status of an athlete prior to HA commencement. Individuals presenting with a fever or upper respiratory tract infection are predisposed to EHI [92, 93] and should not perform HA sessions for risk of further harm to themselves and their fellow athletes. Although HA does not appear to alter the immune response in healthy individuals [25, 94], athletes with suspected immune suppression may avoid further inflammatory exacerbation by avoiding HA sessions.

5 Perspectives

The purpose of this current opinion piece was to address practical considerations for integrating HA within an athlete's programme and stimulate new research. When considering an HA approach several factors need to be reviewed in order to determine the appropriate heat load (temperature and humidity), mode, intensity, duration, frequency and periodization of adding heat to the existing training plan (Fig. 2). Often the priorities of training and the confines of an athlete or team's schedule and location outweigh the ability to implement best-practice HA. Advancing research offers potential solutions to overcome

Table 2 Possible factors contributing to individual athlete responses to heat response testing and acclimation

Factor	Influence on heat response testing	Influence on HA
Sex	Females have a higher threshold for sweating onset and reduced sweating output compared to males [63, 64]	Females may require MTHA to achieve reductions in T_c and HR seen in males with STHA [24]
Ethnicity	Individuals from hot climates may have greater HSP content and enhanced sudomotor function [6, 65–68]	Faster HA kinetics in individuals from hot climates [59]
Athlete type	Enhanced evaporative cooling in endurance versus sprint athletes [69]	Specific athlete type differences unknown, however, can relate to $\dot{V}O_{2max}$ (see below)
Training status	Higher $\dot{V}O_{2max}$ relates to greater HSP content and exercise heat tolerance [33, 70, 72]	Higher $\dot{V}O_{2max}$ relates to faster rates of HA induction and greater heat tolerance following HA [33, 70]
Body size	Larger body size results in lower body surface area to body mass ratio, and higher heat strain in body mass dependent exercise [73, 74]	Not specified in literature
Body composition	Higher adiposity and mesomorphy results in a faster rise in T_c [75–77]	Higher adiposity is directly related to $\dot{V}O_{2max}$ (see Athlete type) [70]
HA history	Reduced heat strain in subsequent HRT with ~2–4 week of prior HA [30–33, 35]	HA may occur more rapidly with 2–4 sessions [31, 32, 35]
EHI history	Possible early test termination and higher end T_c [78]	HA is possible; some may require repeated HA interventions until enhanced heat tolerance is shown [78, 79]
Menstrual cycle	Tc reduction (0.1–0.2 °C) and increase (0.2–0.5 °C) prior to and following ovulation, respectively [82–84]	Females can heat acclimate, regardless of menstrual cycle phase, following MTHA [24, 81, 87] STHA may be less effective [24, 88]
Oral contraceptives	Combined pill use causes higher T_c (0.5 °C) and cyclical fluctuations may be dampened Progesterone-only pills reduce T_c (0.6–0.7 °C) [84, 85]	Oral contraceptive users can acclimate similarly to non-users [86]
Spinal cord injury	Inability to sweat below the site of injury [90]; reduced exercise intensity for a given rise in T_c with greater lower body heat storage [91]	Partial HA through reduced T_c and PV expansion, without changes in sweat rate [89]
Immune status	Fever or URTIs may increase EHI risk [92, 93]	HA may not change immune markers but increases protection from EHI [94]

EHI Exertional heat injury, *HA* heat acclimation, *HR* heart rate, *HRT* heat response test, *HSP* heat shock protein, *MTHA* moderate-term HA, *STHA* short-term HA, T_c core temperature, *URTI* upper respiratory tract infection, $\dot{V}O_{2max}$ maximal oxygen consumption, *w* week

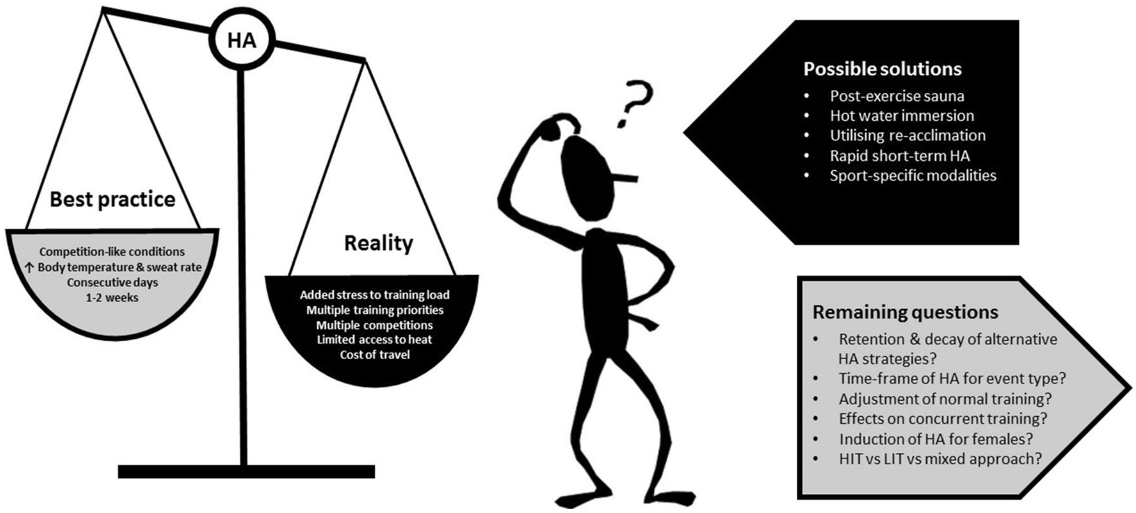

Fig. 2 Integrating best practice heat acclimation (HA) recommendations within the constraints and complexities of an elite athlete's training and competition schedule. *HIT* High-intensity training, *LIT* low-intensity training, ↑ increased

common barriers to HA. Alternatives to conventional HA through post-exercise hot water immersion and sauna bathing add little disruption to normal training and may be used to induce HA adaptations if sport-specific training cannot be performed in a hot environment. While some form of heat exposure prior to competition in the heat would be better than none at all, caution is nevertheless warranted when using alternative forms of HA, and thermoregulatory markers should be monitored to measure heat adaptation progress. Before the length and intensity of HA are chosen, practitioners should consider the event duration and demands, and be aware that short-term HA may not induce the thermoregulatory and performance enhancement that longer-term HA provides. Implementing a re-acclimation strategy prior to an event in hot conditions may offer flexibility for athletes and their schedules when other key elements of training are more crucial. When adjusting routine training, the added stress imposed by HA should be considered, and the volume and intensity of other routine training in normal conditions may need to be reduced based on physiological and subjective athlete feedback during a heat camp. Finally, understanding individual athlete responses to heat stress and HA will assist practitioners to tailor protocols to their individual needs.

6 Conclusion

Heat strain associated with exercise in hot conditions has a negative impact on exercise performance. HA improves thermoregulation and cardiovascular stability, and attenuates heat-induced performance impairments. While the present HA guidelines provide a sound starting point for practitioners working with athletes, new research aimed at reducing the limitations and barriers of translating evidence-based guidelines to the real world of elite sport is needed. Alternative HA methods may be beneficial and easier to apply with athletes. An understanding of how HA may affect established training load would assist practitioners towards optimising the implementation of HA within the complex intricacies of an athlete's training programme. Finally, the unique individual athlete response to HA should be considered when attempting to achieve optimal performance outcomes in hot condition events.

Compliance with Ethical Standards

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Conflict of interest Julia Casadio, Andrew Kilding, James Cotter and Paul Laursen declare that they have no conflicts of interest relevant to the content of this review.

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