Practical Implementation Strategies for Heat Acclimatization and Acclimation Programming to Optimize Performance

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ABSTRACT

Repeated exercise heat exposures enhance exercise performance through a complex series of adaptations that are referred to as heat acclimatization (HAz), which occurs in an artificial environment, and heat acclimation (HA), which occurs in a natural environment. Special considerations are needed to induce adaptations and verify HAz and HA status. To ensure the effectiveness of each session, sufficient duration of exercise-induced hyperthermia is required. To this end, environmental conditions and exercise frequency, intensity, time, type, volume, and progression can be adjusted to achieve optimal adaptations. Furthermore, adaptations are typically lost within 1 week to 1 month following the cessation of exercise heat exposure and maintenance of adaptations is an important factor. Additionally, selecting the appropriate testing procedure is critical to ensure an athlete's HAz and HA status. The purpose of the current study was to provide various HAz and HA frameworks based on different sports so clinicians can implement HAz and HA to optimize performance. **[*Athletic Training & Sports Health Care*. 2021;13(4):e238-e246.]**

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Given the increased participation of athletes in outdoor sports, the known decrement in performance when exercising in hot environmental conditions, and the high incidences of exertional heat illness in sports (232 exertional illnesses were reported in 5 years in National Collegiate Athletic Association athletes), it is important to fully understand the physiological, psychological, and performance responses of athletes to physical activity in the heat.[1-4] A better understanding of athletes' responses in the heat allows for the development of mitigation strategies to enhance exercise performance and safety. The most effective strategies for enhancing performance and safety in the heat are heat acclimatization (HAz) and heat acclimation (HA).

Greater physiological strain, such as an increased heart rate and internal body temperature, is placed on the body when an athlete exercises in a hot environment compared to a temperate environment.[5] HAz and HA are systematic and repeated heat exposures to induce a set of adaptations, which are important to reduce the incidence of heat illness for athletes who exercise in the heat but can also be an effective agent to reduce thermoregulatory and cardiovascular strain to enhance an athlete's performance in hot and cold environments.[5-7] HAz describes heat-related adaptations that are performed in a natural environment (eg, high ambient temperature during normal training outside), whereas HA refers to adaptations elicited from an artificial hot environment (eg, environmental chamber).[8] This study aims to provide a framework, rationale, and example scenarios to assist sport coaches, strength and conditioning coaches, and athletic trainers in developing appropriate HAz and HA protocols.

PERFORMANCE ENHANCEMENT

What Are the Benefits of HAz and HA? One of the most rapid adaptations observed following HAz and HA

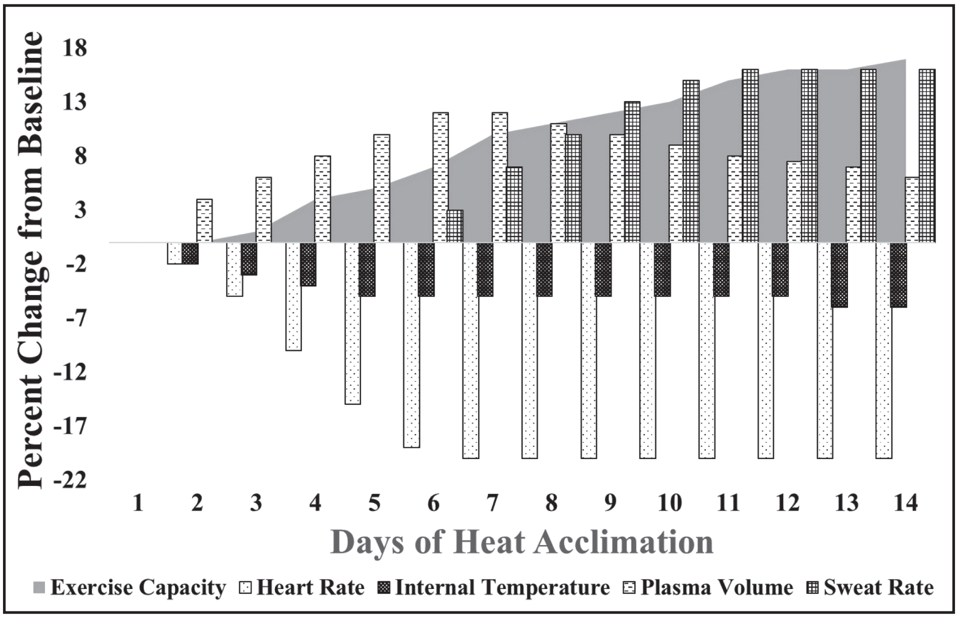

Figure 1. The percent change in plasma volume, heat rate, internal temperature, sweat rate, and exercise capacity throughout induction in heat acclimation. Created using data from Periard JD, Racinais S, Sawka MN. Adaptations and Mechanisms of Human Heat Acclimation: Applications for Competitive Athletes and Sports. *Scand J Med Sci Sports*. 2015;25(Suppl 1):20-38. doi:10.1111/sms.12408

is increased plasma volume leading to increased stroke volume and decreased heat rate, which typically occurs within 3 to 6 days of exercise heat exposure.[8,9] The range of plasma volume expansion can be 3% to 27%, which corresponds to decreases in heart rate by 15% to 25%.[7,10,11] These adaptations are a result of the expansion of total body water via increases in aldosterone and arginine vasopressin secretion and total plasma protein.[8,11] These adaptations also contribute to a better maintenance of cardiac output and blood pressure during exercise.[7] An increase in cardiac output likely explains the approximately 5% improvement in VO_{2max} following HA, which leads to performing exercise at a lower relative intensity when absolute workload is matched.[8] Additionally, perceived exertion and thermal sensation improve in the relatively early stages of exercise heat exposure during the HAz and HA processes.[5,11]

Arguably the most important adaptation to HAz and HA is the decrease in internal body temperature at a similar exercise intensity in similar environmental conditions. Resting and exercising rectal temperature decrease approximately 0.18 and 0.34 °C, respectively, within 5 to 8 days of exercise heat exposure.[5,8,11] This allows for an increased effort at a relative exercise intensity that can lead to more effective training or enhanced performance.

Another important adaptation is the increased retention of electrolytes from the sweat glands.[7] Sodium and chloride concentrations in sweat decrease within 5 to 10 days of exercise heat exposure, which leads to better conservation of electrolytes[9] and helps to increase total body water.[8] Furthermore, the initiation of sweating and the increase of skin blood flow at milder environmental conditions start earlier with exercise heat exposure so that heat dissipation through these mechanisms begins at the lower internal temperature.[5,8] Additionally, sweat rate increases within 8 to 14 days of exercising heat exposure.[9] This results in an evaporative heat loss of up to 11%.[12]

Metabolic changes are also observed following exercising heat exposure. Blood and muscle lactate accumulation are reduced during submaximal exercise due to a decrease in oxygen uptake and glycogen utilization at a given exercise intensity.[5,8] This reduction has been shown to increase power output.[7,13] This can be beneficial for sports in which glycogen depletion can cause fatigue, such as marathon or ultra-endurance running.[14]

Beneficial adaptations that occur with repeated exercise heat exposures include plasma volume expansion, higher sweat rate, lowered internal temperature, decreased heart rate, improved maintenance of cardiac output, reduced oxygen demand, less reliance on glycolysis, improved perceived exertion and thermal comfort, and greater power output at lactate thresholds.[5,7,8] **Figure 1** shows the percent change in plasma volume, heart rate, internal temperature, sweat rate, and exercise capacity throughout HA. All of the factors mentioned previously contribute to increased exercise performance following heat acclimatization, especially in sports that require strong aerobic or anaerobic capacity such as running, cycling, soccer, and American football. A lower internal temperature has been found to be an advantage in intermittent sprints performance,[15] which is related to team intermittent sports (soccer, lacrosse, rugby, American football, etc). Exercise heat training may lead to an improvement in exercise performance, not only in the heat but also in temperate and cool conditions.[13] Thus, exercising heat exposure has advantages to exercise in both hot and cool environments.

HEAT ACCLIMATIZATION AND SPECIAL CONSIDERATIONS

How Do I Know if Someone Is Heat Acclimated?

In light of the adaptations that occur, the three following variables can be used to assess heat acclimatization in a field setting: (1) lower rectal temperature or ingestible thermistor at the same environmental conditions and exercise intensities; (2) lower heart rate at the same environmental conditions and exercise intensities; and (3) increased sweat rate at the same environmental conditions and exercise intensities during a repeated test protocol.[5,7] For additional evidence supporting HAz and HA, lower rating of perceived exertion (Borg Scale), thermal sensation, and lower environmental symptoms questionnaire scores can also be evaluated during the testing protocol.[5,16] This could be a useful, safe, and effective framework that may provide sports scientists, athletic trainers, strength and conditioning specialists, and sport coaches with a tool to evaluate an athlete's acclimatization and acclimation status.

How Can I Ensure My Athletes Maintain HAz and HA Benefits?

Adaptations achieved by HAz and HA are typically lost within 1 week to 1 month following the cessation of exercise heat exposure.[17] Maintenance of HAz and HA is arguably the most important factor in this process because, similar to maintenance of fitness throughout a competitive season, the physiological benefits obtained during this process are crucial to optimize performance. When HAz or HA is accomplished, maintaining the benefits and adaptations allows for enhancing performance in hot and cold environments, along with maintaining safety for athletes exercising in the heat.[13,18] Maintenance of HAz and HA is commonly achieved via one to two heat exposures per week following the appropriate acclimatization or acclimation protocol.[19] The timing of maintenance is also critical because the benefits of HAz and HA decay rapidly. Because HA is intense training, having athletes complete HA a few weeks before the competition and avoid large amounts of training in the heat right before competition by maintaining HA adaptations is helpful to achieve peak performance. One study demonstrated that 35% of acclimation benefits (heart rate and internal temperature) were lost after 2 weeks without heat exposure.[20] Another study showed that approximately 100% of heart rate and 50% of internal temperature losses occurred after 3 weeks without heat exposure.[21] Therefore, ensuring appropriate heat exposures following HAz and HA protocol is crucial for the athlete's performance.[17,22]

What Factors Should I Consider for HAz and HA Sessions?

Internal Body Temperature. To ensure that each HAz and HA session is effective, internal body temperature should be monitored throughout the exercise session, with each session eliciting sufficient hyperthermia over an adequate duration of time to elicit desired physiological and psychological adaptations.[7] Although a minimum temperature of 38.5 °C and duration of at least 60 minutes has been recommended for this response, HAz and HA should be based on individual responses to exercise in the heat because several variations of protocols have been successful.[7,18] Rectal thermometer and ingestible thermometer are the two most common methods of collecting internal body temperature during exercise. Tympanic, aural, oral, skin, temporal, and axillary temperature are not valid assessments of this measurement and should not be used to assess internal temperature.[23] All of the following variables can be adjusted based on this internal temperature criterion. Optimal internal temperature is critical to achieve performance benefits. Similar to other aspects of training, optimal adaptations require the application of an appropriate load.[7] Similar to aerobic or strength training, HAz and HA can be thought of as a supercompensation response. Adaptations obtained by HA have been shown to be maximum 3 days following HA induction.[24] Too little load, in this case rise in internal temperature, will result in suboptimal adaptations. Meanwhile, too much load can put an individual at risk for exertional heat illnesses.[25]

Environmental Conditions. When using the natural environment to achieve HAz and HA, environmental conditions should be appropriately monitored with valid measures of ambient temperature and relative humidity, or with a wet-bulb globe temperature device that incorporates ambient temperature, humidity, and radiant heat load.[7] When using an artificial setting (heat laboratory, indoor facility, etc) environmental conditions can be altered, based on the desired exercise intensity, to achieve sufficient hyperthermia. The primary environmental conditions that can be altered are ambient temperature and relative humidity, unless in a facility that can allow for precise radiant heat exposure. Coaches should consider the environmental conditions of the target competition to guide selection of the environmental conditions and optimize the benefits of HAz and HA.[7]

Exercise Frequency, Intensity, Time, Type, Volume, Progression Model for HAz and HA

Frequency. The frequency of the HAz and HA protocol should be based on the needs analysis of the team or individual. Daily heat exposure is the fastest way to obtain adaptations, although two sessions in 1 day does not appear to enhance this process.[26] When daily heat exposure is not feasible, intermittent heat exposures can also be conducive for achieving adapatations.[27]

Intensity. The intensity of the sessions can be based on several variables (eg, VO_{2max}, heart rate, and the internal body temperature).[17] If internal temperature is measured during these sessions, the intensity can be adjusted throughout the sessions to obtain adaptations. If internal temperature is not measured, the session intensity should be above 50% VO_{2max}.[9] Although laboratory-grade VO_{2max} values may not be achievable in a practical setting, there are several validated tests that can be used to estimate an athlete's VO_{2max}, including the Yo-Yo Intermittent Recovery Level 2 test, 1.5-mile run, and 12-minute run test.[28,29] Additionally, sports training can be used to induce HAz.[30]

Time: Circadian Rhythm. Based on the nature of circadian rhythm, attainability of HAz and HA is more conducive to exercise in the afternoon.[31] This can decrease the overall training intensity and volume on the athlete when considering time to reach the hyperthermia and training time.

Time: Before Competition. To ensure maximum benefits, coaches should consider completing HAz or HA at least 2 weeks prior to the competition of interest and begin implementation of the maintenance protocol to reduce training stress and peak for the target competition.[24] If HAz or HA is desired for a longer period, such as throughout an entire season, the maintenance protocol discussed above should be implemented to prevent decay.

Environmental Variation Throughout Competitive Season. Coaches should also consider the environmental conditions of each sport and how that affects an athlete's HAz and HA status. For example, fall sport athletes (eg, football, soccer, and cross-country) typically train in warm environmental conditions throughout the summer and during pre-season to prepare for their competitive season, and therefore, start the season heat acclimatized and may benefit from a maintenance protocol.[32-34] Spring athletes (eg, track and field and field hockey), who typically begin their season in cooler environmental conditions and are not heat acclimatized, would benefit from HA training to prepare for warmer competitions later in the season.

Type. HAz and HA can use sport-specific exercise modalities to achieve the adaptations as long as athletes are monitored appropriately to ensure the safety of the athlete's exercise in the heat.[35] Alternatively, exercise modalities that reduce the training stress of the athlete can also be used to achieve adaptations (biking, incline walking, etc). Alternative methods, such as sauna and wearing extra clothing, can be used to induce adaptations; however, exercise is needed to achieve optimal adaptations.[35,36] When alternative methods are used, coaches and athletes should strongly consider combining those alternative methods with exercise to achieve maximum performance enhancement.[35]

When an environmental chamber is not available, a small enclosed room can be used to induce or maintain HA. To create this room, select a room that is large enough to add exercise equipment but small enough to sufficiently heat with space heaters. Use a wet-bulb globe temperature monitor to determine the environmental conditions in the room throughout all exercise sessions, because temperature and humidity can rise substantially with exercise to maintain appropriate environmental conditions. Internal body temperature should also be continuously monitored in this setting to ensure safety.[25] Additionally, extreme fatigue and exhaustion during exercise should be avoided to reduce the risk of heat illnesses, such as exertional heat stroke and exertional heat exhaustion, and to perform sessions safely.[25]

Volume. As with any additional training stress, coaches should consider the total physical and mental

TABLE 1

Heat Testing Procedures for Cross-Country Athletes[a]

Primary factors	
Internal body temperature	Measured with ingestible thermistor or rectal thermometer
Environmental conditions	≥ 35.0 ºC, ≥ 50% relative humidity
FITT-VP (secondary factors)	
Frequency	Before and after induction plan
Intensity	Estimate for athlete to reach in 30 to 45 minutes, approximately 70% to 80% of heart rate reserve
Time	Time for internal temperature to reach 39.0 or 102.2 ºC
Type	Running
Volume	Consider balance between training and heat acclimation
Progression	Not applicable
Athlete responses	Heart rate, chest strap
Internal body temperature	Rectal thermometry, ingestible thermometer
Fluid intake	Weigh water bottle before and after exercise
Sweat rate	See **Table A**
Perceptual measures	Rating of perceived exertion, thermal sensation scale

FITT-VP = frequency, intensity, time, type, volume, and progression
[a]Goal: Time for internal body temperature to reach 39.0 ºC before and after the procedures. Internal body temperature should be monitored and used as the stopping criterion for the test. The testing information will be used to determine if the heat training protocol elicited the desired physiological responses.

TABLE 2

Heat Exposures for Cross-Country Athletes[a]

Primary factors	
Internal body temperature	Between 38.5 and 39.75 ºC
Environmental conditions	Can be adjusted for internal temperature
FITT-VP (secondary factors)	
Frequency	10 sessions, sessions should be no more than 3 days apart
Intensity	Maintain internal body temperature between 38.5 and 39.75 ºC
Time	Warm up for 15 to 30 minutes until internal temperature reaches 38.5 ºC. Train for 60 minutes of internal body temperature is above 38.5 ºC
Type	Running or biking
Volume	Consider balance between training and heat acclimation
Progression	Progressive increase in intensity and environmental conditions
Athlete responses	Heart rate, chest strap
Internal body temperature	Rectal thermometry, ingestible thermometer

FITT-VP = frequency, intensity, time, type, volume, and progression
[a]Goal: Induction of heat acclimation. Athletes should aim for internal temperatures between 38.5 and 39.75 °C to fully elucidate the heat acclimation adaptations. Modifiable factors for this training include: frequency, intensity, time, type, volume, and progression. Type of exercise was chosen based on muscle mass used during exercise that increases the metabolic heat produced; however, other exercises with large muscle groups used continuously could certainly be used. Throughout a heat acclimation induction protocol, intensity and environmental conditions should be gradually increased with each session to maintain safety and not overwhelm the thermoregulatory system too quickly.

demands placed on the athlete.[35] If HAz or HA is desired for improved sport performance, other training volume, intensity, or duration may need to be modified to ensure the athlete does not overtrain or develop maladaptations.[35] It is important to note that HAz can be achieved in the scope of the athlete's normal training, as long as sufficient hyperthermia is met during those sessions.

Progression. Intensity, time, environmental conditions, and volume should be increased gradually over the course of the protocol.[5] To achieve the adaptations, intensity and environmental conditions are the two primary modifiable variables.

Fluid Intake. Coaches should ensure that athletes are consuming adequate fluid to maintain euhydration to minimize fluid loss and reduce the risk of heat illness during exercise.[37] Fluid intake can be prescribed based on losses (before to after body mass measures) and sweat rate (**Table A**, available in the online version of this article).[38]

Safety. Gradual implementation of heat exposures is important to maintain the safety of all players.[39] Special considerations are needed for at-risk populations, such as those taking medications that could affect thermoregulation and fluid balance and individuals with a past history of heat illness or sickle cell trait. These individuals may need careful monitoring of internal temperature.

HAz AND HA SCENARIO

The following tables provide examples of how the methods described in this study can be used in real-

TABLE 3

Maintenance of Adaptations for Cross-Country Athletes[a]

Primary factors	
Internal body temperature	Between 38.5 and 39.75 °C
Environmental conditions	Same as the last induction session
FITT-VP (Secondary factors)	
Frequency	≥ 2 times per week
Intensity	Maintain internal body temperature between 38.5 and 39.5 °C
Time	Warm up for 15 to 30 minutes until the internal temperature reaches 38.5 °C Train for 60 minutes until the internal body temperature is above 38.5 °C
Type	Running or biking
Volume	Consider balance between training and heat acclimation
Progression	Not applicable
Athlete responses	Heart rate, chest strap
Heart rate	Chest strap
Internal temperature	Rectal thermometry, ingestible thermometer

FITT-VP = frequency, intensity, time, type, volume, and progression
[a]Goal: Keep all benefits gained from induction. Athletes should aim for internal temperatures between 38.5 and 39.75 °C to fully maintain adaptations. Modifiable factors for maintenance include: frequency, intensity, time, type, volume, and progression. Type of exercise was chosen based on muscle mass used during exercise that increases the metabolic heat produced, but other exercises with large muscle groups used continuously could certainly be used.

TABLE 4

Testing Protocol for Team Sport Athletes[a]

Primary factors	
Internal body temperature	Between 38.5 and 39.75 °C
Environmental conditions	35.0 °C, 50% relative humidity
FITT-VP (secondary factors)	
Frequency	Before and after induction plan
Intensity	Steady state exercise, approximately 70% to 80% of heat rate reserve
Time	60 minutes
Type	Running, biking
Volume	Consider balance between training and heat acclimation
Progression	Not applicable
Athlete responses	
Heart rate	Chest strap
Internal body temperature	Rectal thermometry, ingestible thermometer
Fluid intake	Weigh water bottle before and after exercise
Sweat rate	See **Table A**
Perceptual measures	Rating of perceived exertion, thermal sensation scale

FITT-VP = frequency, intensity, time, type, volume, and progression
[a]Goal: Internal body temperature and sweat rate increase and heart rate decreases from before to after induction. Rating of perceived exertion and thermal sensation scale can be used as supplementary evidence of heat acclimation and heat acclimatization. In the presence of increased sweat rate, decreased heart rate, and decreased rectal temperature, decreased rating of perceived exertion and thermal sensation scale add to the likelihood of attainment of heat acclimation and heat acclimatization.

world scenarios. Testing procedure, HAz, HA, and maintenance examples are described for different sports with different goals in mind. Data sheets that can be used for testing, training, rating perceived exertion, thermal sensation, and thirst scale are provided in **Tables B-F**, available in the online version of this article, respectively. Although these are examples, strength and conditioning can use these scenarios to create HAz and HA protocols for their athletes.

Scenario 1

A team of distance runners has been training in cold weather for the previous 2 months. They will be competing in extremely warm weather or cool weather in 4 weeks. HA can improve exercise performance in not only in the warm weather, but also in the cold conditions. The following methods can be used to ensure they are going to peak for their race. **Table 1** indicates the method of assessing responses to the heat prior to HA, primary factors that will be considered for this test, examples of the exercise frequency, intensity, time, type, volume, and progression model, and the outcome variables that will be assessed. Athletes run until their internal body temperature reaches 39.0 °C and their performance will be based the amount of time it takes them to reach that temperature (more time indicates greater adaptation). The internal body temperature is monitored by rectal or ingestible thermometer. **Table 2** shows an example of the induction program. Athletes perform 75 to 90 minutes of running or biking and maintain the internal body temperature above 38.5 °C for 60 minutes. They perform this induction session 10 total times. **Table 3** indicates the method to maintain adaptations with approximately two times of heat training per week, with the same training method as induction.

TABLE 5

Heat Exposure for Team Sports Athletes

Primary factors	
Internal body temperature	Between 38.5 and 39.75 ºC
Environmental conditions[b]	35.0 ºC, 50% relative humidity
FITT-VP (secondary factors)	
Frequency	10 to 14 sessions, sessions should be no more than 3 days apart
Intensity	Soccer training session Average heart rate approximately 80% of heart rate reserve
Time	Warm up for 15 to 30 minutes Train for 60 minutes
Type	Soccer, running, and/or biking
Volume	Consider balance between training and heat acclimatization
Progression	Progressive increase in intensity and environmental conditions
Athlete responses	
Heart rate	Chest strap
Internal temperature[c]	Rectal temperature, ingestible thermometer

FITT-VP = frequency, intensity, time, type, volume, and progression

[a]Goal: Induction of heat acclimatization or acclimation. Athletes should aim for internal temperatures between 38.5 and 39.75 °C to fully elucidate the heat acclimation and acclimatization adaptations. Modifiable factors for this training include frequency, intensity, time, type, volume, and progression. Type of exercise was chosen based on muscle mass used during exercise that increases the metabolic heat produced, but other exercises with large muscle groups used continuously could certainly be used. Throughout an induction protocol, intensity and environmental conditions should be gradually increased with each session to maintain safety and not overwhelm the thermoregulatory system too quickly.

[b]Outside of a laboratory, environmental conditions are going to be difficult to control, so the authors recommend alternative methods to induce adaptations such as increasing clothing layers while also monitoring internal temperature.

[c]Monitoring internal body temperature will likely only be feasible in a laboratory setting, although monitoring of internal temperature is highly recommended in all training sessions in the heat.

TABLE 6

Maintenance Adaptations for Team Sport Athletes[a]

Primary factors	
Internal body temperature	Between 38.5 and 39.75 ºC
Environmental conditions[b]	35.0 ºC, 50% relative humidity
FITT-VP (secondary factors)	
Frequency	≥ 2 times per week
Intensity	Soccer training session Average heart rate approximately 80% of heart rate reserve
Time	Warm up for 15 to 30 minutes until internal temperature reaches 38.5 ºC Train for 60 minutes until the internal body temperature is above 38.5 ºC
Type	Soccer, running, and/or biking
Volume	Consider balance between training and heat acclimatization
Progression	Not applicable
Athlete responses	
Heart rate	Chest strap
Internal temperature[c]	Rectal temperature, ingestible thermometer

FITT-VP = frequency, intensity, time, type, volume, and progression

[a]Goal: Keep all benefits gained from induction. Athletes should aim for internal temperatures between 38.5 and 39.75 °C to fully maintain adaptations. Modifiable factors for maintenance include frequency, intensity, time, type, volume, and progression. Type of exercise was chosen based on muscle mass used during exercise that increases the metabolic heat produced, but other exercises with large muscle groups used continuously could certainly be used.

[b]Outside of a laboratory, environmental conditions are going to be difficult to control, so the authors recommend alternative methods to induce adaptations such as increasing clothing layers while also monitoring internal temperature.

[c]Monitoring internal body temperature will likely only be feasible in a laboratory setting, although monitoring of internal temperature is highly recommended in all training sessions in the heat.

Scenario 2

A soccer team has been training in cold weather for the previous 2 months. They will be competing in extremely warm weather in 4 to 5 weeks. The following methods can be used to ensure they are going to peak for the game. **Table 4** indicates the method to assess baseline responses. This testing includes 60 minutes of steady state exercise to examine the changes in internal body temperature, sweat rate, and heart rate before and after HAz or HA. **Table 5** demonstrates the example of HAz or HA. The goal is to maintain the internal body temperature above 38.5 °C for 60 minutes with running, biking, or soccer. Athletes perform HAz or HA training a total 10 to 14 times. **Table 6** indicates the method to maintain adaptations, which consist of approximately two times of heat training per week, with the same training method as induction. It is important to consider the balance between soccer training and HAz or HA training.

IMPLICATIONS FOR CLINICAL PRACTICE

HAz and HA induce positive physiological, perceptual, and performance adaptations. To ensure the effectiveness of each HAz and HA session, sufficient duration of exercise-induced hyperthermia is required. To this end, environmental conditions and the exercise frequency, intensity, time, type, volume, and progression model can be adjusted to achieve optimal adaptations. Furthermore, adaptations are typically lost following the cessation of exercise heat exposure and maintenance of adaptations is an important factor. Future research needs to investigate the optimal procedures to maintain adaptations following HAz and HA. Additionally, it is critical to examine the factors to change the magnitude of adaptations in each individual.

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Table A

Heat Acclimation Testing Data Sheet

Athlete Name__________________ Testing#_______ Date____________________

Pre BM______________(kg) Post BM______________(kg) Fluid intake_________(kg)

Pre Fluid Bolus Mass_____________(kg) Post Fluid Bolus Mass_____________(kg)

Time	Internal Temperature	HR	RPE	Thermal	Ambient Temperature	Humidity	Note
0							
5							
10							
15							
20							
25							
30							
35							
40							
45							
50							
55							

END: Time__________________

Internal Temperature___________________ HR_______________

RPE__________________ Thermal___________________

Temperature________________ Humidity________________

.

Table B

Heat Acclimation Training Data Sheet

Name___________________ Trial #_____________ Date_____________________

Pre BM_______________(kg) Post BM_______________(kg) Fluid intake__________(kg)

Pre Fluid Bolus Mass______________(kg) Post Fluid Bolus Mass______(kg)

Time	Speed/Resistance	Internal Temperature	HR	Ambient Temperature	Humidity	Note
	/					

Table C

Rating of Perceived Exertion Scale

6	
7	Very, Very Light
8	
9	Very Light
10	
11	Fairly Light
12	
13	Somewhat Hard
14	
15	Hard
16	
17	Very Hard
18	
19	Very, Very Hard
20	

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Table D

Thermal Sensation Scale

0.0	Unbearable Cold
0.5	
1.0	Very Cold
1.5	
2.0	Cold
2.5	
3.0	Cool
3.5	
4.0	Comfortable
4.5	
5.0	Warm
5.5	
6.0	Hot
6.5	
7.0	Very Hot
7.5	
8.0	Unbearably Hot

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Table E

Thirst Scale

1	Not Thirsty At ALL
2	
3	A Little Thirsty
4	
5	Moderately Thirsty
6	
7	Very Thirsty
8	
9	Very, Very Thirsty

Created using data from Engell DB, Maller O, Sawka MN, Francesconi RN, Drolet L, Young AJ. Thirst and fluid intake following graded hypohydration levels in humans. *Physiol Behav.* 1987;40(2):229-236. doi:10.1016/0031-9384(87)90212-5

Table F

Sweat Rate Calculation Instructions

1. Before the exercise, ensure the athlete is hydrated (light colored urine). Being dehydrated may affect normal sweat rate.
2. Take nude body mass before the start exercise.
3. Perform exercise.
4. If water is consumed, weigh the water before and after the exercise to determine the amount of fluid intake.
    A. Pre water weight: _______kg
    B. Post water weight: _______kg
    C. A – B: ___________kg fluid consumed
5. After the exercise take another body weight and calculate the difference between pre and post exercise.

    D. Pre-exercise nude body mass: _______kg
    E. Post-exercise nude body mass: _______kg
    F. D – E: ___________kg body mass loss

6. Pre and post body weight, fluid intake, and exercise duration are used to **calculate sweat rate** (L·hour^{-}1) with the following equation.

    (F + C) × 60 / exercise duration (min)

Note: Every 2.2 pounds a person loses equates to 1 liter of fluid loss (sweat loss). For example, if someone loses 5 pounds in 1 hour their sweat rate is 5/2.2 = 2.27 liters·hour^{-1}. Similarly any liter of fluid consumed = 33.8 fluid oz. Please note that urinating during this test will skew results. Ideally if an individual needs to urinate the urine should be weighed and added back into the post weight value in order to avoid urine losses being mistakenly calculated as sweat losses.

Created using data from Adams JD, Sekiguchi Y, Suh H-G, et al. Dehydration impairs cycling performance, independently of thirst: a blinded study. *Med Sci Sports Exerc.* 2018;50(8):1697-1703. doi:10.1249/MSS.0000000000001597