Body-Cooling Paradigm in Sport: Maximizing Safety and Performance During Competition

By: William M. Adams, Yuri Hosokawa, and Douglas J. Casa

Adams WM, Hosokawa Y, Casa DJ. Body-Cooling Paradigm in Sport: Maximizing Safety and Performance During Competition. *Journal of Sport Rehabilitation.* 2016;25(4):382-394.

*****Note: Tables may be found at the end of this document.**

Abstract:

Context: Although body cooling has both performance and safety benefits, knowledge on optimizing cooling during specific sport competition is limited. **Objectives:** To identify when, during sport competition, it is optimal for body cooling and to identify optimal body-cooling modalities to enhance safety and maximize sport performance. **Evidence Acquisition:** A comprehensive literature search was conducted to identify articles with specific context regarding body cooling, sport performance, and cooling modalities used during sport competition. A search of scientific peer-reviewed literature examining the effects of body cooling on exercise performance was done to examine the influence of body cooling on exercise performance. Subsequently, a literature search was done to identify effective cooling modalities that have been shown to improve exercise performance. **Evidence Synthesis:** The cooling modalities that are most effective in cooling the body during sport competition depend on the sport, timing of cooling, and feasibility based on the constraints of the sports rules and regulations. Factoring in the length of breaks (halftime substitutions, etc), the equipment worn during competition, and the cooling modalities that offer the greatest potential to cool must be considered in each individual sport. **Conclusions:** Scientific evidence supports using body cooling as a method of improving performance during sport competition. Developing a strategy to use cooling modalities that are scientifically evidence-based to improve performance while maximizing athlete's safety warrants further investigation.

Keywords: cooling modality | body temperature | cooling rate | review

Article:

Athletes competing in competitive sports strive to maximize athletic performance (increased strength, faster completion times in timed aerobic and anaerobic events, increased cognition in sport-specific skills, and increased exercise capacity in competitions of set time duration) to perform at the highest level. During competition, especially in the heat, it is not uncommon for athletes to reach body temperatures in the range of 39°C to 40°C, which could have negative effects on performance and increase the risk of heat illness.[1,2] To combat these potentially deleterious effects, athletes often use various body-cooling techniques to lower or mitigate the rise in body temperature during competition.

There are currently 2 hypotheses that account for the negative physiological and performance effects that increasing body temperature has on athletic performance: the critical-temperature hypothesis and the anticipatory hypothesis. The critical-temperature hypothesis centers on the concept that the body will decrease intensity when body temperature reaches a "critical threshold" of 40°C to prevent exertional heat stroke (EHS) from occurring.[1,3,4] The anticipatory model states that the brain will anticipate the increase in body temperature and thus alter intensity during exercise to prevent body temperature from reaching unsafe levels.[5–7] In both theories, exercise performance is negatively affected as body temperature increases. Keeping the body cool during competition allows athletes to perform for longer periods and at a higher intensity, especially during intense exercise in the heat.[8–10]

The ability to enhance recovery after an intense bout of exercise has received increasing attention, especially at the professional and elite settings, where athletes are looking to find a legal, competitive edge over their opponents. Exercise elicits a stress response on the body, primarily from the increase in body temperature during exercise. Reducing the level of stress on the body after exercise by lowering body temperature helps the body recover more quickly and thus allows it to perform better in subsequent training sessions or competitions.[11] Postexercise cooling has been shown to reduce inflammation, heart rate, and cardiac output and to provide analgesic effects that can assist in reducing recovery time.[12–14]

At rest, body temperature is closely regulated at or close to 37°C. However, during exercise, body temperature increases due to the metabolically produced heat from the exercising muscles.[2] To regulate the increase in body temperature, mechanisms of conduction, convection, and evaporation are used to dissipate heat. When the body is under uncompensable heat stress and is unable to dissipate heat at the rate at which it is produced, the risk of EHS drastically increases and it becomes crucial for rapid body cooling to minimize the time that rectal temperature is above 40°C.[15–18] If the body is not rapidly cooled, the complications and prognosis of EHS may include renal failure, liver failure, rhabdomyolysis, coagulopathy, cardiac disorders (eg, arrhythmia, congestive heart failure, hypotension), pulmonary disorders (eg, pulmonary edema, respiratory distress syndrome), central nervous system damage, cognitive impairment, and death.[15,17,19] In the context of EHS treatment, the National Athletic Trainers' Association[20] and American College of Sports Medicine[21] have published guidelines that indicate whole-body cold-water immersion (CWI) as the most effective cooling method.

Objectives

While evidence has shown that body cooling during competition has performance, recovery, and safety benefits, there are no comprehensive reviews on how to use body cooling to maximize athletic performance during competition. The purpose of this review is 2-fold: to identify when during sport competition it is optimal for body cooling and to identify optimal body-cooling modalities to enhance safety and to maximize sport performance. Throughout this review, *performance* refers to factors associated with improved outcomes in sport competition: increased strength, faster completion times in timed aerobic and anaerobic events, increased cognition in sport-specific skills, and increased exercise capacity in competitions of set time duration.

Review of Cooling Modalities

Various cooling modalities are available to assist with body cooling before, during, and after competition. The decision to use specific cooling modalities during sport competition is based on the individual sport, the timing to implement the cooling modality (precompetition, during competition, postcompetition), accessibility, space required to use the cooling modality, and the equipment or clothing requirements of the sport. The following sections outline the most commonly used cooling modalities and the associated scientific evidence that supports their implementation in body cooling.

Whole- or Partial-Body CWI

Due to water's capacity for thermal conductivity and potential for heat transfer, whole-body CWI is very effective in decreasing body temperature and is considered the gold standard for treatment of EHS.[22,23] Evidence also supports CWI as an effective modality to enhance performance when used before exercise and postexercise.[13,24] Reducing body temperature before competition permits athletes to exercise at a higher intensity by increasing heat-storage capacity, which can improve performance. Reducing body temperature quickly after competition allows for improved recovery, thus providing potential performance enhancements for subsequent bouts of exercise. CWI, both whole-body and partial-body, is implemented by submersing the body into circulating ice water (~2–10°C) until body temperature is lowered to determined levels.[25,26] CWI has the ability to reduce body temperature at the cooling rates of 0.25°C/min to 0.35°C/min, which is the fastest and most efficient method in the current literature.[27–2-]

Water Dousing

Water dousing can be used to cool the body but is only recommended when it is implemented continuously, such as with a cold shower or cold water from a hose.[16] Previous literature[30,31] has shown that water dousing is sufficient in cooling the body when applied for 45 to 60 minutes. While evidence shows that water dousing can decrease body temperature in the range of 0.6°C to 2.5°C,[30,31] the rate of cooling is affected by the water temperature and the duration of treatment time. In a competitive sports setting, water dousing is best used after competition in enhancing postexercise recovery[13] to prevent decrements in performance during subsequent bouts of exercise due to the amount of time it requires to effectively cool the body.

Ice Towels

Ice-towel application can be an alternative method to cool the body when an immersion tub is not accessible.[32] Improvements in exercise performance have been observed with application of ice towels before the start of exercise,[33,34] but limited evidence exists on the effect of ice towels on performance when used during exercise. Ice towels can be implemented with ease and low cost, requiring only a few towels, ice, water, and a cooler. To implement, a cooler (or any container what will hold liquid) is filled with ice and water and the towels are submerged into the ice water. The ice towels are then placed on the athlete and rotated. They should be recooled every 2 to 3 minutes, covering as much body surface as possible to obtain a maximal cooling effect. Ice towels can also be used as an effective modality for athlete safety due to the ability of the ice towel to mitigate the rise in body temperature and to allow for expedient reduction in body temperature after exercise; the cooling rate for ice-towel application is 0.1°C/min.[35,36]

Ice Bags

Placing ice bags on the peripheral arteries is often seen in the athletic setting to help reduce body temperature. Placing ice bags over the peripheral arteries, in areas such as the axillae, groin, and back of the neck, allows the blood passing through the arteries to be cooled. The cooled blood then circulates to the rest of the body, which helps lower body temperature. Some evidence has supported the use of ice bags to improve performance, with reported performance improvements on the magnitude of 5.6%.[37] Although this modality is often used due to its accessibility and easy implementation, the extent to which it can cool the body over other modalities is rather low, with a cooling rate on the order of 0.03°C/min.[38]

Fans (With and Without Mist)

Both fans and misting fans that are most commonly seen on the sidelines of American football games are purported to keep athletes cool after they return to the sideline from being on the field. A fan that has an adequate ability to deliver cool air to the athletes may not be practical in other sports such as soccer, basketball, and ice hockey due to the limited space on the sideline. In addition, the average cooling rate for methods that use fans are rather poor, ranging from 0.02°C/min to 0.11°C/min. The relatively lower cooling rate refers to when only the fan is used, and the relatively higher cooling rate refers to when the fan is used in conjunction with cold-water mist.[36,39,40] In addition, there is no evidence examining the influence of fan use on improved performance, thus prompting further investigation into the applicability of its use in sport settings.

Hand Cooling

Hand cooling refers to cooling the hands and/or forearms to elicit a reduction in body temperature. Evidence has supported that cooling the hands and forearms in cold water has resulted in the mitigation in the rise of body temperature.[41,42] Other technologies available to athletes are devices that cool the body by placing one's hand in a chamber, where cold water is continuously circulated concomitantly while a negative pressure is applied to the hand. These devices have shown the ability to attenuate the rise in body temperature during exercise[43,44] by applying subatmospheric pressure to draw blood into the hand, which vasodilates the veins returning blood to the heart. The concurrent circulation of cold water cools the venous blood entering the hand, which then returns to the heart to help cool the body. Evidence has also supported the use of hand cooling in reducing physiological heat strain[44] and improving performance.[43,45] While there is evidence showing that hand cooling attenuates the rise of body temperature during exercise and improves performance, its effectiveness in preexercise and postexercise body cooling remains questionable due to the low cooling rate of 0.05°C/min.[43,46,47]

Head Cooling

For the purposes of this review, head cooling refers to a method in which a device is worn on an athlete's head. Head-cooling devices are available in different forms: from cooling helmets that store cold water in the inner portion of the helmet to devices that use both air and liquid pumps that function to pressurize and circulate chilled coolant to the outer, middle, and inner layers of the headliner. The surface of the cooling device possesses the ability to cling closely to the skin, which further encourages the heat transfer between the unit and the athlete's skin via conduction. Few studies have evaluated the ability of a head-cooling device to reduce body temperature. Hayashi and Tokura[48] found that body temperature during exercise was attenuated during approximately 60 minutes of cycling in a hot environment when head cooling was worn. In contrast, Mündel et al[49] and Ansley et al[50] discovered that body temperature postexercise was unchanged when head cooling was used compared with no cooling. The effect of head cooling on exercise performance is limited, although evidence does support its use in increasing time to fatigue.[50]

Ice/Cooling Vest

Ice/cooling vests are designed to hold cold compresses in close proximity to the torso's skin surface to optimize cooling via conduction. Other ice/cooling vests also exist that use convection and phase change to invoke body cooling while being worn. Due to their portability, ice/cooling vests can be used before competition, during breaks (such as halftime), and throughout competition itself. Since the athletes are not likely to be logistically compromised from the use of ice/cooling vests before competition, this modality may be more practical to use than CWI, which requires athletes to take the time to immerse themselves in a tub of water before competition. While some studies showed attenuation in the rise in body temperature and heart rate and improvement in performance,[51–53] other studies observed no significant improvement in performance.[54,55] The conflicting evidence regarding the effectiveness of ice/cooling vests can be partially attributed to the cooling rate, as it is reported to be 0.05°C/min.[39]

Cooling Garments

Loose-fitting, moisture-wicking clothing made of synthetic fibers has been shown to promote heat loss via enhanced evaporation of sweat and increased airflow to the skin.[56] This type of clothing allows the heat trapped in the microenvironment created between the garment and body to be dissipated more efficiently.[57] In addition to wearable clothing, there are products (ie, cooling towels) that stimulate the evaporative cooling mechanism by having layers of micropores within the fabric that "actively" cool the skin by using the enthalpy of vaporization. Although moisture-wicking clothing is the apparel of choice when exercising in the heat, no research has demonstrated the effectiveness of the evaporative cooling capacity of the fabric to actively cool the body and enhance athletic performance in the heat.[58]

Hydration

Hydration is the most widely used tool to keep athletes cool during exercise. It is well established in the scientific literature that fluid losses greater that 2% of body mass loss can cause deleterious effects on exercise performance.[59,60] More specifically, body-mass losses of greater than 2% have been shown to decrease overall strength, power, aerobic capacity, and cognition.[61,62] In addition to the detrimental effects on exercise performance, literature has shown that for every 1% loss of body mass due to dehydration, temperature increases at a rate of 0.22°C and heart rate increases 3 beats/min.[63,64] Beginning exercise in a hypohydrated state will cause an athlete to begin exercise at an increased body temperature. In such situations, especially during intense exercise in the heat, the risk of exertional heat illness increases if fluid losses are not minimized. It is recommended that minimizing fluid losses before, during, and after competition with help maintain an appropriate level of hydration and maximize exercise performance.

Ice-Slushy Drinks

Ice-slushy drinks (mixtures of crushed ice with water or other electrolyte-containing beverages) have garnered support to assist in body cooling. The acting mechanism in which the body cools with the slushy drink is by creating a heat sink in the exercising person's visceral organs, thus cooling the body from the core to the periphery. Scientific literature[65–68] has identified ice slushy drinks as being effective in lowering body temperature during exercise and enhancing performance due to increased exercise capacity. Evidence also shows that exercise performance is enhanced when athletes consume cold fluids rather than temperate fluids.[69]

Discussion

As aforementioned, keeping the body cool during competition, by using either precooling strategies or strategies to mitigate the rise in body temperature during competition, has the potential to improve athletic performance.[70] As body temperature increases during exercise, there is a competition within the body as to how the blood is distributed. During exercise, blood is distributed to the skin to dissipate the heat that is produced from the working muscles. Concomitantly, the working muscles require blood flow to receive the oxygen necessary to optimally perform. As body temperature rises, there is an increased demand for blood to be distributed to the skin to further aid in heat dissipation. As the blood flow increases at the skin with the rise in body temperature, the blood available to the muscles will be decreased, thus decreasing their ability to optimally perform.

Sport competition places physiological stress on the body, but each sport places unique physiological strains on the body due to the various demands of the sport (protective equipment worn, length of the competition, playing surface, ability for substitutions, etc). Table 1 represents 18 sports or events along with the characteristics of each sport to demonstrate the uniqueness of each. The aim of this table is to identify times and modes in which cooling modalities can be used in each sport to optimize body cooling during competition, with the hope to enhance performance.

The effect of body cooling on improving performance has been well established in the scientific literature.[11,24,37,51,71] Ranalli et al[51] found 4.25% and 0.66% improvements in aerobic and anaerobic performance, respectively, when cooling modalities were used. Likewise, Wegmann et al[37] found a 6.6% improvement in performance when cooling was used during exercise in the heat, with the largest improvements occurring during endurance events. While cold drinks and cool packs have shown the largest improvements in performance when examining the influence of the modality itself,[37] it is suggested that using multiple forms of cooling may provide a greater benefit for performance.[24]

The timing of body cooling has also been well investigated, particularly with cooling before exercise. The improvement in performance from precooling focuses on the premise that lowering body temperature below its set point before exercise allows athletes to exercise at a higher intensity during exercise as they are afforded a greater temperature gradient before performance is adversely affected.[51,72,73] A recent meta-analytical review[24] found that precooling improved exercise performance by a factor of 5.7% overall, with mixed cooling methods (ie, CWI and cooling vests) providing the largest improvement in exercise performance (7.3%)

Cooling postexercise has also been investigated in that cooling the body postexercise allows athletes to recover more quickly and thus have the potential to improve their performance in subsequent competition.[11,13] It is postulated that high internal thermal loads, often seen after intense exercise in the heat, result in the degradation of exercise performance and lengthen the time for the body to recover.[2] Furthermore, it is believed that exercise-induced hyperthermia causes a centrally mediated reduction in voluntary muscle activation and force that can have adverse effects on performance.[74,75] Morrison et al[76] found that hyperthermia-induced inhibition of voluntary muscle activation was reversed with cooling, and other evidence shows that postexercise cooling had beneficial effects on performance during subsequent bouts of exercise.[77,78] Although further investigation is warranted to determine the exact mechanisms that act on improved performance after postexercise cooling, using cooling after exercise reduces the thermal load placed on the body and enhances the ability to recover.

Cooling during exercise has not been as extensively investigated, but is has been proposed that exercise performance improves by a factor of 7.0% when cooling is implemented.[24] Wearing cooling vests during exercise has shown the greatest improvement in exercise performance (20.4%),[79] whereas other evidence shows that ingesting cold water improves exercise performance by 12.4%.[80] Although cooling during exercise has shown improvements in performance, difficulties will arise when attempting to implement 1 modality across all sports due to the individual nature of each sport. The rules and regulations of the sport dictate the number of breaks, length of breaks, number of substitutions during play, and protective equipment worn. All of these factors may change the cooling strategies used to mitigate the rise in athletes' body temperature.

Identifying the timing to apply cooling modalities in the sports listed in Table 1 relies on finding the appropriate cooling modalities that are practical to the respective sport and also the period of time required to effectively cool the body given the modality's cooling rate. With a plethora of purported cooling modalities that are available on the consumer market, using modalities that have been shown to be efficacious in mitigating the rise in body temperature during exercise is of utmost importance. Table 2 identifies common cooling modalities that are used in sport settings and indicates both the feasibility and the efficacy of the device itself respective to each sport listed in Table 1.

CWI has been shown to be the most effective in resulting in a large decrease in body temperature. Although evidence supports using CWI to improve performance, there is also evidence supporting a performance decrement.[81,82] Determining the length of cooling is essential, as evidence indicates that aerobic performance improvements have been shown in most cases when there was a 1.5°C drop in body temperature before exercise, whereas drops of 1.9°C in body temperature have shown a decline in aerobic performance.[82] Depending on the cooling modality used, the length of the cooling period, especially during preexercise cooling, should be considered. Having knowledge of the cooling rates of the modalities is helpful for determining the appropriate length of cooling that will result in favorable outcomes.

In terms of cooling efficiency, CWI has been shown to have the highest cooling rate in cooling hyperthermic athletes.[83] However, it should be noted that the practicality of this method varies between sports due to the rules and regulations of each sport. In American football, for example, CWI is only feasible during the postcompetition period due to the athletes' protective equipment and the inability for them to readily cool the body unless the equipment is taken off. However, contrary to American football, soccer provides more opportunities to use CWI as a cooling modality due to the minimal equipment needed to participate in the sport. Thus, soccer athletes have the ability to use CWI pregame, during halftime, and postgame for body cooling.

Regardless of the practicality of the cooling modalities, the sport itself could also lead to the inability to implement body cooling. For example, professional and international-level soccer only allow a maximum of 3 substitutions throughout an entire game. This means that all but 3 athletes will be required to play the entire game. A new rule at the international level permits a fourth substitution in the event that a competition needs overtime to decide the outcome. This new rule, however, may not provide benefit for the other athletes required to play the entire match. If the game is in a location of extreme environmental conditions such as what occurred in Brazil during the 2014 World Cup and the 2016 Olympic Games, athletes are confronted with extreme conditions that could pose both performance and health risks while their ability to cool during the game is limited. For soccer, when environmental conditions exceed 32°C wet bulb globe temperature an additional 5-minute break is allotted during both the first and second halves, which allows an added opportunity for athletes to use an effective form of body cooling. In cases where the construct of the sport itself limits the times and abilities to cool, these athletes would benefit from using modalities such as CWI during pregame, halftime, and postgame since the rate at which they will cool is maximized versus other modalities.

Another consideration in identifying the timing and practicality of cooling modality is its efficacy. Although numerous types of modalities are used during sport (misting fans, head-cooling devices, hand-cooling devices, etc), there is a lack of evidence supporting the effectiveness of these devices in cooling the body at a rate in which performance benefits are noticeable. Further consideration must be taken into account for cooling modalities that create the perception of cooling when in reality there is no change in body temperature or a greater increase in postexercise body temperature.[66,67,84,85] The perception of feeling cool to improve performance is at odds with safety; athletes perceiving that they feel cool when physiologically there are no changes in body temperature may increase their risk of heat illness. Future research examining these cooling modalities must be done to identify their benefit, not only with their ability to effectively cool the athlete for performance gains and risk mitigation but also in terms of cost-effectiveness, as some cooling modalities could be costly in a team-sport environment.

Conclusions

Mitigating the rise of body temperature during athletic competition acts as both an ergogenic aid for improving performance and a safety measure for preventing heat illnesses such as EHS. Since optimal timing to cool the body varies across sports, it becomes crucial to identify sport-specific cooling modalities to be used to maximize body cooling during competition. Coaches, athletic trainers, and strength and conditioning coaches should be cognizant of effective cooling modalities and implement cooling strategies based on available scientific literature. Cooling plans should include which cooling modalities to use, how long to use them, and when to use them during competition.

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Table 1. Summary of Individual Sport Characteristics in Terms of Competition Rules and Regulations

Sport	Level	Game type	Duration	Halftime duration[a]	Substitutions	Equipment
American football	Professional	Quarters	15 min	12 min	Unlimited	Helmet
	College	Quarters	15 min	20 min	Unlimited	Shoulder pads
	High school	Quarters	12 min	20 min	Unlimited	
Soccer	World Cup	Halves	45 min	15 min	Max. 3; no reentry	Shin guards
	Professional	Halves	45 min	15 min	Max. 3; no reentry	
	College	Halves	45 min	15 min	No reentry	
	High school	Halves	40 min	10 min	Unlimited	
Basketball	Professional	Quarters	12 min	15 min	Unlimited	None
	College	Halves	20 min	15 min	Unlimited	
	High school	Quarters	8 min	10 min	Unlimited	
Baseball	Professional	Innings	9 min	Variable	No reentry	Helmet, chest protector, shin guards (catcher)
	College	Innings	9 min	Variable	No reentry	
	High school	Innings	7 min	Variable	No reentry	
Softball	Professional	Innings	7 min	Variable	No reentry	Helmet, chest protector, shin guards (catcher)
	College	Innings	7 min	Variable	No reentry	
	High school	Innings	7 min	Variable	No reentry	
Decathlon	Olympic	10 events	2 d	N/A	N/A	None
	College	10 events	2 d	N/A	N/A	
	High school	10 events	2 d	N/A	N/A	
Heptathlon	Olympic	7 events	2 d	N/A	N/A	None
	College	7 events	2 d	N/A	N/A	
	High school	7 events	2 d	N/A	N/A	
Running	100K	Race	62.1 miles	N/A	N/A	None
	Marathon	Race	26.2 miles	N/A	N/A	
	Half-marathon	Race	13.1 miles	N/A	N/A	
	10K	Race	6.2 miles	N/A	N/A	
Cycling	Professional	Race	Race-dependent	N/A	N/A	None
	College	Race	Race-dependent	N/A	N/A	
	Amateur	Race	Race-dependent	N/A	N/A	
Triathlon	Full Ironman	Race	140.6 miles	N/A	N/A	None
	Half Ironman	Race	70.3 miles	N/A	N/A	
	Olympic	Race	31.93 miles	N/A	N/A	
	Sprint	Race	16 miles	N/A	N/A	
Tennis	Professional	Game, set, match	Best of 3 sets	N/A	N/A	None
	Majors	Game, set, match	Best of 5 sets	N/A	N/A	
	College	Game, set, match	Best of 3 sets	N/A	N/A	
	High school	Game, set, match	Best of 3 sets	N/A	N/A	
Motor racing	NASCAR	Race	Race-dependent	N/A	N/A	Helmet
	Indy car	Race	Race-dependent	N/A	N/A	Flame-retardant clothes
Men's lacrosse	Professional	Quarters	15 min	12 min	Unlimited	Helmet
	College	Quarters	15 min	10 min	Unlimited	Shoulder pads
	High school	Quarters	12 min	10 min	Unlimited	Chest protector
Women's lacrosse	Professional	Halves	30 min	10 min	Unlimited	Eye guard
	College	Halves	30 min	10 min	Unlimited	Chest protector (goalie)
	High school	Halves	25 min	10 min	Unlimited	
Ice hockey	Professional	3 periods	20 min	17 min[b]	Unlimited	Helmet; chest protector; thigh, shin, elbow pads; gloves
	College	3 periods	20 min	12 or 15 min[b]	Unlimited	
	High school	3 periods	15–17 min	15–20 min[b]	Unlimited	
Rowing (8)	Olympic	Race	2000 m	N/A	N/A	None
	College	Race	2000 m	N/A	N/A	
	High school	Race	2000 m	N/A	N/A	
Rugby	Professional	Halves	40 min	10 min	Max. 7; no reentry	Scrum cap
	College	Halves	40 min	10 min	Max. 7; no reentry	
	High school	Halves	30–35 min	10 min	No reentry in the first half	
Wrestling	Olympic	3 periods	3 min	N/A	N/A	None
	College	3 periods	3-2-2 min[c]	N/A	N/A	
	High school	3 periods	2 min	N/A	N/A	

[a] Duration of halftime in baseball and softball refers to the variation in time that the offensive team has on the bench and their opportunity to cool during this time. [b] The intermission time between the first and third periods in ice hockey. [c] The breaks in minutes between the first, second, and third periods.

Table 2. Optimal Cooling Modalities and Times of Implementation Across Sport Competition

Sport	Cooling opportunity	Cold-Water Immersion: Whole body	Cold-Water Immersion: Partial body	Water dousing	Ice towel	Ice bag	Misting fan	Head-cooling device	Hand-cooling device	Ice/cooling vest	Cooling garment	Hydration (15–21°C)	Slushy drink
American football	Pregame		∇	Δ	Δ	Δ	Δ		Δ		Δ	•	∇
	Offensive or defensive sides			Δ	Δ		Δ		Δ		Δ	•	Δ
	Halftime		Δ		Δ	Δ		Δ	Δ		Δ	•	Δ
	Postgame	•	•	Δ	Δ	Δ		Δ	Δ		Δ	•	Δ
Soccer	Pregame	∇	•	∴	Δ	Δ		Δ	Δ	∇	Δ	•	∇
	Halftime	•	•	∴	Δ	Δ		Δ	Δ	Δ	Δ	•	Δ
	Postgame	•	•	∴	Δ	Δ		Δ	Δ	Δ	Δ	•	Δ
Basketball	Pregame	•	•		Δ	Δ		Δ	Δ	∇	Δ	•	∇
	Substitutions				Δ	Δ					Δ	•	Δ
	Halftime		∴		Δ	Δ		Δ	Δ	Δ	Δ	•	Δ
	Postgame	•	•	∴	Δ	Δ		Δ	Δ	Δ	Δ	•	Δ
Baseball, softball	Pregame		∇		Δ	Δ	Δ	Δ	Δ	∇	Δ	•	∇
	Between innings (while batting)		Δ		Δ	Δ	Δ	Δ	Δ		Δ	•	Δ
	Postgame	•	•	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	•	Δ
Running (competitive)	Prerace	∇	•	∴	Δ	Δ	Δ	Δ	Δ	•	Δ	•	∇
	During race			Δ							Δ	•	Δ
	Postrace	•	•	∴	Δ	Δ	Δ	Δ	Δ	Δ	Δ	•	Δ
Cycling (competitive)	Prerace	∇	•	∴	Δ	Δ	Δ	Δ	Δ	•	Δ	•	∇
	During race			∴							Δ	•	Δ
	Postrace	•	•	∴	Δ	Δ	Δ	Δ	Δ	Δ	Δ	•	Δ
Rowing	Prerace	∇	•	∴	Δ	Δ		Δ	Δ	∇	Δ	•	∇
	During race			∴							Δ	•	Δ
	Postrace	•	•	∴	Δ	Δ		Δ	Δ	Δ	Δ	•	Δ
Rugby	Prematch	∇	•	∴	Δ	Δ		Δ	Δ	∇	Δ	•	∇
	Halftime	∴	∴	∴	Δ	Δ		Δ	Δ	Δ	Δ	•	Δ
	Postmatch	•	•	∴	Δ	Δ		Δ	Δ	Δ	Δ	•	Δ
Wrestling	Prematch	∇	•	∴	Δ	Δ		Δ	Δ	∇		•	∇
	Postmatch	•	•	∴	Δ	Δ		Δ	Δ	Δ		•	Δ

• is identified as the optimal cooling modality with scientific evidence to support its use. ∇ is identified as a feasible cooling modality to use that is based on scientific evidence. ∴ and Δ are optimal and feasible modalities to use, respectively; however, their use in improving performance is not scientifically based. Blank cells indicate that cooling modality is not feasible for the sport and time period.