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Effect of Half Time Cooling on Thermoregulatory Responses and Soccer-Specific Performance Tests

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ABSTRACT

This study examined two active coolings (forearm and hand cooling, and neck cooling) during a simulated half-time recovery on thermoregulatory responses and subsequent soccer-specific exercise performance. Following a 45-min treadmill run in the heat, participants (N=7) undertook 15-min recovery with either passive cooling, forearm and hand cooling, or neck cooling in a simulated cooled locker room environment. After the recovery, participants performed a 6×15-m sprint test and Yo-Yo Intermittent Recovery Level 1 test (YYIR1) in a temperate environment. During the 15-min recovery, rectal temperature fell significantly (p<0.05). Neither active coolings induced further reduction in rectal temperature compared to passive cooling. No effect of active coolings was found in repeated sprint test. However, neck cooling reduced (p<0.05) the thermal sensation (TS) compared to passive cooling during the 15-min recovery. Active coolings attenuated (p<0.05) the sweat rate compared to passive cooling: 1.2±0.3 $l \bullet h^{-1}$ vs. 0.8±0.1 $l \bullet h^{-1}$ vs. 0.8±0.3 $l \bullet h^{-1}$, for passive cooling, forearm and hand cooling, and neck cooling, respectively. For passive cooling, elevated sweat rate resulted in higher (p<0.05) dehydration (2.1±0.3%) compared to neck cooling (1.5±0.3%) and forearm and hand cooling (1.4±0.3%). YYIR1 was improved (p<0.05) following forearm and hand cooling (869±320 m) and neck cooling (814±328 m) compared to passive cooling (654±311 m). Neck cooling (4.6±0.6) reduced (p=0.03) the session TS compared to passive cooling (5.3±0.5). These results suggest that active coolings effectively improved comfort and sweating response, which delayed exercise-heat induced performance diminish during a second bout of exercise.

Key words: *football, body temperature, ice, immersion, sweating, fatigue.*

Introduction

Soccer is characterized by high-intensity intermittent exercise[1]. The high rate of energy expenditure generates considerable amount of body heat which severely elevates the body temperature and sweating response, especially if match play is held in the heat[2]. It has been well documented that elevated heat storage and dehydration would reduce both aerobic[3] and repeated, intermittent sprint performance[4]. Nevertheless, major soccer championship events or pre-season training sessions are often scheduled during the summer time. The heat strain from the environment along with the high metabolic heat production of soccer activities can pose great challenges to players' health, performance and consequently, match results.

In order to optimize performance and ensure safe health practice, many cooling interventions have been studied and it is well accepted that active cooling could offset exercise-heat stress[5,6]. Sports such as soccer, rugby, and tennis, which have one or multiple short periods of recovery between exercise, employing cooling during those short recovery periods may represent the most practical situations for cooling and provide beneficial effects for subsequent exercise periods.

Finding a simple yet effective cooling strategy is difficult, especially for administration in team sports such as soccer. Forearm and hand cold water immersion is easy to perform and provides proven physiological benefits for hyperthermic individuals[5]. Alternatively, neck cooling could be another ideal choice for field application since it is quick and convenient for mass distribution to multiple players[7]. To date, neither of these methods have been evaluated in a soccer match setting. Therefore, this study assessed the efficacy of two active coolings (forearm and hand cooling, and neck cooling) on thermoregulatory responses and soccer-specific exercise performance after a simulated 45-min soccer running in the heat. We hypothesized that active coolings during a simulated 15-min half-time recovery could attenuate heat strain and enhance subsequent soccer-specific performance tests.

Materials and Metods

Seven physically active, heat acclimatized university students (6 male, 1 female) participated in this study. They were informed of the nature of the study, signed the informed consent, and performed a graded treadmill exercise (for assessing maximal oxygen uptake) and familiarization session first. They were asked to refrain from caffeine, alcohol, and strenuous exercise at least 24 hours before each trial. Participants were also instructed to log their food intake the day before the first experimental trial and keep the same food intake before the subsequent trials. In addition, they were instructed to keep euhydrated the day before the experimental trials and ingest ~500

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ml beverage 2 hours before reporting to the lab. While in general there is no gender difference in sweating and core temperature responses to heat stress[8], for the one female participant, all trials were conducted in the same phase of the menstrual cycle to avoid temperature variation. This study was approved by the University's Medical Ethics Committee for protection of human participants.

This study required participants performing three trials in a counterbalanced order. All trails were separated by a week, and performed at the same time of the day (±1 h) with participants wearing soccer uniform. Each trial consisted of a 45-min simulated half of soccer running in a controlled heat chamber, followed by a simulated 15-min half-time recovery consisting of one of the following treatments: a control condition with only passive cooling, which simulates the conditions in an air conditioned locker room, active forearm and hand cooling, or active neck cooling in the same temperate environment as passive cooling, followed by soccer-specific performance tests. The soccer-specific performance tests consisted of 6×15-m sprint test and Yo-Yo intermittent recovery level 1 test (YYIR1). The 6×15-m sprint test was used to measure repeated sprint ability, which is an important physical ability in modern soccer[9]. The YYIR1 has been significantly correlated to maximal oxygen uptake, the amount of high-intensity running, and total distance covered during a soccer match[10,11], thus it provides a valid measurement of a player's endurance ability. These two performance tests were conducted in a temperate environment on a wooden surface area at an indoor facility.

Simulated 45-min soccer specific treadmill run

The 45-min simulated soccer match half was conducted in a heat chamber with wet bulb globe temperature (WBGT) 30.5°C (36°C dry bulb, 28°C wet bulb, 36°C black globe; 50% relative humidity). Participants were weighed (wearing soccer uniform), and then self-inserted a rectal thermocouple (Physitemp, Clifton, USA). The rectal temperature (T_{re}) was monitored with a portable system (Physitemp Thermalert model TH-8, Clifton, USA). A heart rate (HR) monitor (Polar Electro Inc., Lake Success, USA) was worn throughout the trial. T_{re} and HR were recorded every 5 min. Participants were asked to numerically identify their ratings of thermal sensation[12] (TS) during the trials. After instrumentation, participants entered the heat chamber and started to run on a motor-driven treadmill (Q55xt, Series 90, Quinton Instrument Co, Seattle, USA). A 45-min treadmill intermittent running protocol was used to simulate a soccer match running and the activity pattern of this protocol was similar to that observed from time-motion analysis of competitive match play[1,13]. Each locomotor activity and duration was categorized as stand (0 $km \cdot h^{-1}$, 60 sec), walk (5 $km \cdot h^{-1}$, 60 sec), jog (8 $km \cdot h^{-1}$, 30 sec), low-intensity run (10 $km \cdot h^{-1}$, 30 sec), moderate-intensity run (12 $km \cdot h^{-1}$, 30 sec), high-intensity run (14 $km \cdot h^{-1}$, 30 sec), and sprint (16 $km \cdot h^{-1}$, 10 sec). The order of these activities was designed to replicate the intermittent nature of soccer match play. Fluid (tap water) was available during the 45-min period.

15-min cooling/recovery period

Immediately following the treadmill run, participants exited the heat chamber and sat in a room with an ambient temperature 20.7±0.5°C and 45±4% relative humidity for 15 min. Participants sat either with passive cooling, forearm and hand cooling, or neck cooling. For the forearm and hand cooling, participants immersed their left forearm and hand in 12°C cold water and this water temperature was continuously monitored and maintained. The other arm was not immersed in the cold water so that participants could ingest fluid during this period. For the neck cooling, participants put a cold and wet towel around their neck, and every 3 min, a replacement towel was provided. All towels were placed in 5°C ice water for 10 min before the cooling period started. Fluid was available during this period. T_{re}, HR, and TS were recorded every 5 min.

6×15-m sprint test

After the simulated 15-min half-time recovery period, participants moved to a room with an ambient temperature 20.7±0.5°C and 45±4% relative humidity. Relocating from the laboratory to the room required approximately 30 sec of light intensity walking. Then participants completed a 6×15-m sprint test, with 30 sec of rest between each sprint. Participants were instructed to approach the line with 10 sec left before the next sprint and were provided a 5 sec countdown before the start of each sprint. Infra-red timing lights (Speed Trap II Wireless Timing System, Power-Systems, Inc., Knoxville, USA) were used to record the time of each sprint. Sprint time and HR were recorded after each sprint. T_{re} and TS were recorded at the end of the entire 6 × 15-m sprint test.

Yo-Yo intermittent recovery level 1 test

Approximately 4 min (brief rest while listening to the audio play of test instruction) after the 6×15-m sprint test, participants completed a YYIR1[10] at the same location. HR was recorded after finishing each stage of YYIR1. T_{re} and TS were also recorded at the end. Upon completion of the YYIR1, participants returned to the laboratory and were weighed again with the same clothes. Total fluid ingestion was measured, and change in fluid balance was calculated from pre- and post- body weight adjusted by fluid ingestion. Twenty minutes after the trial, participants reported their session TS.

A two-way Analysis of Variance (ANOVA) was used to determine differences for T_{re}, HR, TS, and sprint time. When a significant *F* ratio was found, Fisher's LSD *post hoc* test was performed to identify the individual differences. A one-way ANOVA was used to compare any differences among treatments for sweat rate, fluid balance, and session TS with Fisher's LSD *post hoc* procedure. A paired *t*-test was used to determine the difference of YYIR1 score with Bonferroni correction of the alpha value. Using a one-tailed alpha of $p<0.05$ at a power of 90% and a sample size of 7 and the mean observed standard deviation of change in YYIR1, individual data were analyzed to determine the responders to the cooling treatment. All statistical analyses were performed using SPSS version 21 (IBM, Armonk, USA). Statistical significance was accepted as $p \leq 0.05$. Values are presented as mean±standard deviation.

Results

Participants' age, height, weight, body fat percentage, and maximal oxygen uptake were 25±4 yr, 175±8 cm, 73.3±10.4 kg, 9±4% body fat, and 57.0±6.7 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively. Of the total 21 trials, only one trial was terminated due to muscle cramp during YYIR1, and for this participant the distance covered before stopping was recorded as the total distance covered for YYIR1.

Responses to 45-min intermittent running

Physiological and thermal responses over the experiment are given in Table 1. T_{re}, HR, and TS at the end was no different among the trials ($p>0.05$) (Table 1).

Responses to 15-min cooling/rest period

After 15-min recovery, T_{re} fell significantly ($p<0.05$, Table 1) with all three conditions in the fairly comfortable environment, equals to -0.7±0.1°C vs. -0.7±0.3°C vs. -0.8±0.3°C relative to the start of the recovery, for passive cooling, forearm and hand cooling, and neck cooling, respectively. However, active coolings did not induce further reduction in T_{re}. Recovery HR was no different at any time point among the three trials (Table 1). TS decreased over the time period (Table 1). A significant main effect for trial revealed that, after 5 min rest TS was significantly lower during neck cooling than passive cooling ($p<0.05$); and TS for neck cooling was also significantly lower compared to forearm and hand cooling at 10 and 15 min ($p<0.05$).

TABLE 1
PHYSIOLOGICAL AND THERMAL RESPONESES
(MEAN±STANDARD DEVIATION, N=7)

	Start of 45-min run	End of 45-min run	Recovery at 0-min	Recovery at 5-min	Recovery at 10-min	Recovery at 15-min	End of sprint test	End of YYIR1
Heart rate (beats·min^{-1})								
Passive cooling	94±18	169±18	123±12	104±15	92±11	87±11	156±22	194±8
Forearm and hand cooling	88±10	161±26	117±11	96±12	87±10	87±12	162±20	192±7
Neck cooling	94±11	162±20	113±8	95±15	87±12	88±12	152±21	194±8
Rectal temperature (°C)								
Passive cooling	37.8±0.4	39.0±0.5	39.0±0.5	38.8±0.5	38.6±0.5	38.3±0.5*	38.4±0.5	38.9±0.4
Forearm and hand cooling	37.5±0.2	38.9±0.4	39.0±0.4	38.5±0.5	38.2±0.4*	38.0±0.4*	38.3±0.3	38.8±0.4
Neck cooling	37.5±0.3	38.9±0.4	39.0±0.5	38.8±0.4	38.5±0.4*	38.2±0.3*	38.4±0.3	38.8±0.4
Thermal sensation								
Passive cooling	4.0±1.2	6.4±0.4	4.9±1.1	4.4±1.0	4.1±0.9	3.6±0.7†	4.4±0.8	5.3±0.9
Forearm and hand cooling	4.4±0.7	5.9±0.3	5.1±0.9	3.9±1.1†	3.6±0.9†	3.4±0.6†	4.1±0.5	5.3±0.8
Neck cooling	3.9±0.6	5.9±0.5	4.7±1.0	3.0±0.7†‡	2.5±0.8†‡§	2.2±0.6†‡§	3.9±0.4	4.6±1.0

Legend: YYIR1 – Yo-Yo intermittent recovery level 1 test. For the ratings of thermal sensation, each number represents the following: 8–“Unbearably Hot”, 7–“Very Hot”, 6–“Hot”, 5–“Warm”, 4–“Comfortable”, 3–“Cool”, 2–“Cold”, 1–“Very Cold”, 0–“Unbearably Cold”. *(rectal temperature) significantly different from start of the 15-min recovery, $p<0.05$; †(thermal sensation) significantly different from start of the 15-min recovery, $p<0.05$; ‡(thermal sensation) neck cooling significantly different from passive cooling, $p<0.05$; §(thermal sensation) neck cooling significantly different from forearm and hand cooling, $p<0.05$

Performance of 6×15-m sprint test

The effects of cooling on multiple sprint performance are presented in Figure 1a. Average times for the six sprints were 2.86±0.16 sec vs. 2.81±0.17 sec vs. 2.83±0.17 sec, for passive cooling, forearm and hand cooling, and neck cooling, respectively. Relative to passive cooling, neither forearm and hand cooling nor neck cooling enhanced the sprint performance. HR was no different at any time point among the trials. At the end of the sprint, no difference of T_{re}, HR, and TS was found among the trials (Table 1).

Performance of YYIR1

Both forearm and hand cooling and neck cooling significantly improved the total distance covered (Figure 1b). The distances covered were 654±311 m (passive cooling), 869±320 m (forearm and hand cooling), and 814±328 m (neck cooling). Five out of the seven participants responded to the cooling treatment (Figure 1b). Rectal temperatures increased rapidly to the level of pre-cooling condition (Table 1). At the end TS were not different among the trials ($p>0.05$, Table 1).

TABLE 2
SWEATING RESPONSE AND FLUID BALANCE
(MEAN±STANDARD DEVIATION, N=7)

	Passive cooling	Forearm and hand cooling	Neck cooling
Fluid ingestion (ml)	968±359	679±292	692±420
Weight loss (kg)	1.5±0.4	1.0±0.2*	1.1±0.3*
Dehydration (%)	2.1±0.3	1.4±0.3*	1.5±0.3*
Sweat rate ((l·h^{-1})	1.2±0.3	0.8±0.1*	0.8±0.3*

*significantly different from passive cooling, $p<0.05$

Sweating response, fluid balance, and overall thermal discomfort

Impact of active coolings on sweating response and fluid balance is given in Table 2. Sweat rate was significantly higher ($p<0.05$) in passive cooling over the trial period when compared to the active coolings. Active coolings significantly attenuated the dehydration ($p<0.05$). Neck cooling (4.6±0.6) attenuated the session TS compared to passive cooling (5.3±0.5) ($p=0.03$), with no difference for forearm and hand cooling (4.9±0.5) ($p>0.05$).

Discusion

This study was designed to examine the impact of half-time cooling on recovery and a second bout of exercise performance. This test protocol, including the 45-min intermittent running, repeated sprint test, and YYIR1, was chosen to simulate the high-intensity, intermittent nature of soccer running activities, to evaluate the external environmental heat load on players when matches are held in high ambient temperatures. The results from this study demonstrate that active coolings during a simulated half-time recovery enhanced thermoregulatory ability by decreasing whole body sweating despite the absence of further reductions in body core temperature. Most importantly, these simple active coolings successfully yielded 42% (forearm and hand cooling) and 31% (neck cooling) improvements in soccer-specific intermittent running performance even in a temperate environment. This increase in exercise capacity could be attributed to the lower sweat rate, dehydration status, and improved thermal comfort.

Water immersion has been suggested to be effective mean to extract the heat from the circulating blood and cool the body core[14]. Using methodology similar to ours (20-min recovery at a room temperature of 15°C), Carter et al.[15] reported a 0.8°C reduction of core temperature (we saw about a 0.7°C drop in 15 min) when participants were cooled via forearm and hand immersion at 10°C of cold water. The current results found all three cooling conditions significantly reduced the body core temperature in 15-min recovery period. However, neither active coolings further enhanced body temperature control during the recovery period and the subsequent bout of exercise compared to passive cooling. The substantially comfortable temperature and humidity in the comfortable laboratory field may have prevented further advantages from active coolings. However, practically from a cooling core temperature standpoint, passive cooling provided enough drive for recovery (body core temperature regulation), where the environment here can be typically found in many locker room settings during the half-time break.

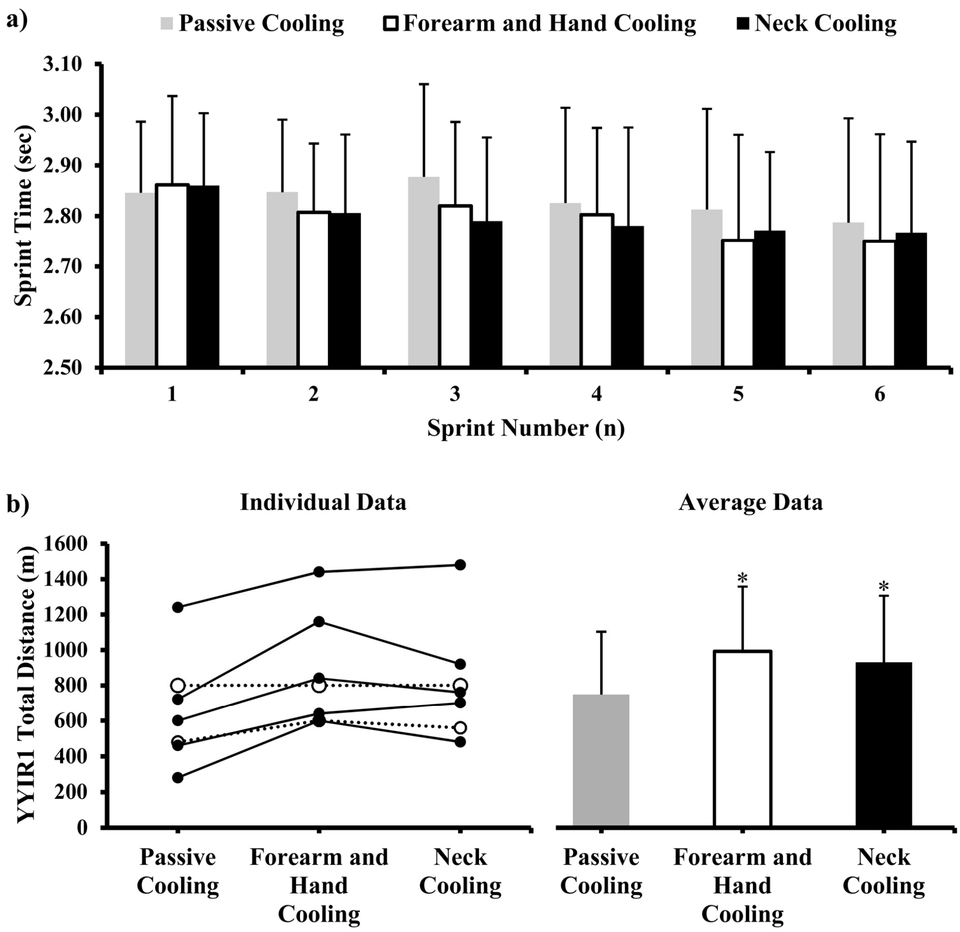

FIGURE 1

ACTIVE COOLINGS ON SOCCER-SPECIFIC PERFORMANCE TESTS: a) 6×15-m repeated sprint test b) Yo-Yo intermittent recovery level 1 test (YYYIR1) (left panel: individual data [● – responder, ○ – non-responder]; right panel: average data) (mean±standard deviation, N=7). *significantly different from passive cooling, $p<0.05$

Any cooling intervention acting as a "heat-sink" can be expected to improve exercise performance in the heat. From our results, there was no beneficial effect of cooling on high intensity sprint ability. Lack of an apparent beneficial effect of cooling on repeated sprint ability has also been reported elsewhere[6,16]. It is possible that, the ative coolings did not differentiate the body core temperature during the recovery period in the simulated locker room environment and therefore did not elicit an improvement in the subsequent sprint performance. In addition, we chose 15-m for the sprint test as an indicator of anaerobic capacity following the earlier fatiguing exercise, since this distance typically reflects the soccer players' running pattern (~14 m) during competitive matches[9]. The current test protocol emphasizing soccer-specific sprint distance and relative adequate recovery may allow sufficient recovery and pose inadequate challenge for the body's thermoregulation system and thus, mitigated beneficial effect of the active coolings.

A single physiological parameter such as a reduction in core temperature may not well reflect the global view of whole body thermoregulation. Crawshaw et al.[17] have shown that local skin cooling can reduce sweating response in the heat even in the absence of an apparent reduction in body core temperature. A recent review[18] concluded that high skin temperature and hypohydration, not high core temperature, are the primary factor impairing aerobic exercise performance. Compared to passive cooling, active coolings reduced the sweat rate by 0.4 $l \cdot h^{-1}$ or ~33% advantage (Table 2) and attenuated dehydration process at the end of the trial. This is similar to the finding using a neck cooling device in which the sweat rate was reduced by 6.4%[7]. The reduced sweat rate could be resulted from enhanced conduction and convection heat loss via cold water and concomitantly, reduced the reliance of body heat dissipation via sweat production and evaporative cooling. Meanwhile, active coolings also improved the perception of comfort during recovery and subsequent exercise. Using cold water immersion or even simple intervention, replacing multiple cold and wet towel of neck cooling, achieved desired physiological benefit. Effect of cooling on comfort and sweating response resulted in significant improvement in distance covered during YYIR1 for forearm and hand cooling (42±37% over no cooling) and neck cooling (31±24% over no cooling) (Figure 1b). It is apparent that even a moderate dehydration (~2.0% for passive cooling) could considerably impact on the submaximal exercise capacity, and such negative effect would be evident if both the environmental temperature and the relative humidity (reduced efficacy for evaporative cooling) are high, and/or in many sport-specific situations, where chances for fluid replenish are restricted.

Based on the current results, there are several points of interests regarding the development of fatigue in soccer. First, a critical high core temperature from strenuous exercise and environmental heat threatens the performance and health of players. As evidenced during the subsequent performance tests (~20-25 min of total time for the sprint test and YYIR1), the core temperature increased rapidly back to the level immediately after the 45-min run (Table 1). This was as a result of the sprint and submaximal run in a temperate environment, and not in the heat, during which it would be expected to observe an even higher core temperature. This would be a great concern, especially if major competitions (e.g., Olympics soccer tournament) or pre-season camps are held in high ambient temperatures in the summer time. The intermittent nature of soccer match play clearly poses evident thermal strain on the body. Furthermore, from the current study, ~2% moderate dehydration (~80 min of total trial time including recovery) was associated with a decline in high-intensity running performance and may play a major role in the development of fatigue. It should be noted that, in our study, fluid (tap water) was freely available and participants were encouraged to drink at all times. During soccer match play, the chances for fluid replenishment would be largely limited, and appropriate rehydration does not always occur.

Due to the nature of the soccer match play, researchers often face problems with in-depth and accurate lab controlled conditions for experimental investigation. A major drawback of the current study design therefore, is that we did not test the subsequent soccer-specific performance in a hot and humid environment. In our study, participants exercised in the heat to simulate soccer match half, and indeed simulated a recovery environment that typically can be found in the field. However, the readers need to acknowledge that the performance protocol was conducted in a moderate/comfortable condition following the pre-load of ~30˚C WBGT. The soccer-specific tests requirement does not allow us to simulate the same heat condition, nor in the summer time as of which are even challenging due to inability to control environmental conditions in multiple summer days. Therefore, readers and researchers need to be aware that in addition to the small sample size in this study, the current study design may lead to an underestimation of the effectiveness of cooling, and doesn't strictly allow to make accurate conclusions about performance changes in the heat.

Conclusion

The present study has demonstrated the practical field benefits (i.e., YYIR1, sweating response) of forearm and hand cooling and neck cooling in delaying the development of dehydration, providing thermal comfort, and improving high-intensity sport performance under exercise-heat stress. For sports such as soccer, tennis, rugby, baseball, and American football that have breaks active coolings before warm-up and during any breaks could aid recovery from heat strain and help in delaying fatigue and enhance subsequent sport performance. Taken together, the current simple effective active coolings are recommended for large field implementation in team sports during hot conditions.

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UTICAJ HLAĐENJA TOKOM POLUVREMENA NA TERMOREGULACIJU I SPECIFIČNE PERFORMASE FUDBALERA

S A Ž E T A K

Ova studija ispituje dvije intervencije hlađenja (aktivnu nasuprot pasivnoj) tokom simulirananog oporavka u poluvremenu na termoregulaciju i kasniji učinak vježbanja. Nakon 45-minutne aktivnosti na pokretnoj traci, ispitanici (N=7) su tretirani 15-minutnim oporavkom, pasivnim hlađenjem podlaktice i šake ili vrata u određenoj prostoriji za ovakve namjene. Nakon oporavka, ispitanici su tretirani 6×15-m sprint testom i Yo-Yo Intermittent Recovery Level 1 testom (YYIR1) u umjereno zagrijanom okruženju. Ni aktivno hlađenje nije izazvalo dalje smanjenje rektalne temperature, niti pasivno. Nije pronađen uticaj aktivnog hlađenja u ponovljenom testu sa sprintovima. Međutim, aktivno hlađenje je izazvalo smanjenje znojenja, toplotni osjećaj (TS) u poređenju sa pasivnim hlađenjem ($p<0.05$). Kod pasivnog hlađenja, povišeno znojenje je rezultirano na nivou 2.1±0.3% dehidratacije u poređenju sa hlađenjem vrata (1.5±0.3%), podlaktice i šake (1.4±0.3%) ($p<0.05$). YYIR1 je značajno unaprijeđen ($p<0.05$) kada je u pitanju hlađenje podlaktice i ruke (869±320m) i hlađenja vrata (814±328m), u poređenju sa pasivnim hlađenjem (654±311m). Navedeni rezultati sugerišu na činjenicu da aktivne intervencije hlađenja efikasno poboljšavaju udobnost i začetak znojenja, koje je bilo usporeno tokom drugog seta vježbi.

Ključne riječi: fudbal, tjelesna temperatura, let, potapanje, znojenje, zamor.