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EFFECTS OF PALMS COOLING ON THE THERMOREGULATORY RESPONSES IN MALE TENNIS PLAYERS

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ABSTRACT

The aim of this study was to investigate the effects of palm cooling using the double hands rapid cooling (DHRC) device on the cardiovascular and thermoregulatory responses, and performances in a hot environment (Wet Bulb Globe Temperature = 31°C) in male tennis players. Twelve male collegiate tennis (mean age of 21.8 ± 2.3 years, weight 66.72±4.9 kg. and height 174±5.1cm) participated in two experimental trials 1) DHRC and 2) Control (N-DHRC) group. The protocol was repeated 12 games in the simulated tennis matches in a randomized manner. Physiological variables and subjective responses included intestinal temperature (T_{int}), heart rate (HR), rating of perceived exertion (RPE) and thermal sensation (TSS) were measured during the first 30 second of 90 seconds break at the odd number of games: 1, 3, 5, 7, 9, and 11. During the breaks, subjects sat in upright position with or without the application of palm cooling in DHRC device, respectively. In DHRC trial, cooling was applied by placing both hands into the device (10 ºC) for 60 seconds of the remaining rest period. Services and ground stroke accuracy were tested before and after the simulated match. Two-way analysis of variance (ANOVA) with repeated measures was used to evaluate for significance of main effects (trial and game), and interaction (trial x game). A paired t-test was performed to compare the difference between trials at rest and at the 1^{st} game (before beginning of the intervention). Results showed that mean wet bulb globe temperature (WBGT), as well as HR and T_{int} at rest and after the 1^{st} were not different between N-DHRC and DHRC trials. During the progression of games, an increase of T_{int} in DHRC trial was significantly slower than N-DHRC conditions (3^{rd} to 11^{th} game). An increase of HR following the 3^{rd} game was greater in N-DHRC compared with palm cooling; DHRC. Significant interactions between trials and number of games on T_{int}, and HR were observed with less increase in DHRC trial. Mean ground stroke accuracy score after the simulated match was greater in the DHRC trial with significant interaction effect. Wilcoxon matched-pairs signed-ranks tests indicate significant lower RPE in DHRC. In conclusion, palm cooling using the DHRC during the 1-min rests between games of simulated tennis match in the heat can effectively lower thermal and cardiovascular strain, and perception of exertion. Additionally, fatigue was less with the application of double hands cooling presenting by a better retention in tennis skill and cardio-respiratory endurance performance.

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KEYWORDS: Thermoregulatory / Palm Cooling/ Cooling Effect / Tennis / Performance

INTRODUCTION

Tennis match play is characterised by intermittent exercise with variable variations in intensity and duration. It has got only 4 – 10 seconds during each point with 10 – 20 seconds recovery period. It also has 60 to 90 seconds break between games[1]. In 2004, International Tennis Federation; ITF established the recovery periods for international tournament which rest time over 20 seconds between each point, 90 seconds between change overs and 120 seconds between each set. The duration of each match can be prolonged between 1 hour and 4 hour. Tennis ~~is~~ usually plays outdoors where the environmental conditions are warm or hot[2]. It is well-known that exercise in hot climates for a long time can lead to strain of cardiovascular and respiratory systems and also induced heat stress compare with neutral condition. In 2000, Tatterson *et al* studied on elite road cyclists about the physiological responses affected by heat stress. The cyclists performed 30-min cycling in 32°C (HT) and 23°C (NT) with 60% RH cycling in an environmental chamber with core temperature and sweat rates were higher especially during the last 10 minutes and their performances were declined in HT compared to NT. It suggested that decreasing in performance is associated with body temperature factors rather than metabolic capacity[4]. Exercise in the heat demands physiological responses particularly in cardiovascular and thermoregulation systems. Therefore, many modalities have been developed to delay increasing of core temperature and decreasing of cardiovascular strain in order to maintain performance. Cooling techniques included water-cooled vests[6,7], cooling suits[7,8], hand cooling[9], palm cooling[10] and Ice packs[7,11] were used in previous studies. In 2008 Goosey and Tolfrey found that hands immersion to the wrist in water at 10°C for 10 minutes reduced auditory canal temperature and performance in the disable athletes[12]. Matthew (2009) investigated the effect of palm cooling during simulated armored vehicle transport in a chamber with temperature set at 42 °C and 36.5% RH. The results have shown that palm cooling reduced thermal strain during recovery period after performed 6.1 km/h and 2-4% grade in a hot, dry environment[10]. Recently, Rapid Thermal Exchange (RTX) has been introduced as one of cooling technique.

Rapid Thermal Exchange (RTX) has been reported as an effective cooling tool in human[13]. Grahn *et, al*. (2008) demonstrated the benefit of cooling about using rapid thermal exchange (RTX) by 35% increasing in exercise duration of walking on treadmill in heat sensitive individuals with multiple sclerosis. Yang *et, al*. (2009) found that RTX resulted in significant lower rectal temperature than passive cooling. Reduction in heat storage enhances human safety and performance in hot environments. However, there was no research on the effect of rapid thermal exchange (RTX) on heat strain reduction and performance improvement in tennis player. The hypothesis of this study was using DHRC can induce different thermoregulatory, cardiorespiratory, subjective evaluation (RPE), and performances in male tennis players. Therefore, the aim of this study was to investigate the effects of palm cooling using the double hands rapid cooling (DHRC) device on the cardiovascular and thermoregulatory responses, and performances in a hot environment in male tennis players.

METHODOLOGY

Subjects

Twelve male tennis players who had at least 2 years of playing experiences and regularly trained for 3 hours, at least three times a week voluntarily participated in this study. Subjects with cardiovascular and respiratory diseases, neuromuscular or skeletal disorders or injury, fever or infections, gastric ulcer, gag reflex sensitive were excluded from the study. Informed consent was obtained from all subjects, and was approved by the Ethical Committee on human experiment of Mahidol University.

Parameters of the study

Heart rate was recorded every 5 seconds using heart rate monitor (Polar Active FT7, USA). Intestinal temperature, an index of core temperature, was monitored using telemetric ingestible thermometer sensor (CorTemp 2000, USA). Subjective evaluations including Thermal sensation scale (TSS) (Gagg et al., 1976), and rating of perceived exertion (RPE) were measured using Borg scale (1962) with score 6 to 20. Tennis skill tests including service and ground accuracy scores were determined.

Experimental design

Each subject completed three visits included familiarization and two experimental trials with a randomized crossover design. The tests were separated at least 3 day. Two experimental trials were conducted either 1) Control trial: subjects rested between games without cooling application (N-DHRC) or 2) Cooling trial: subjects rested between games with palm cooling using DHRC device

On the first visit, body weight, height, BMI, and %body fat were determined. On the second and third visits, all subjects arrived at the tennis court in the morning. Subject ingested the telemetric temperature sensor before starting the experiment about 8-12 hours. At rest, urine sample was collected to evaluate urine specific gravity and hydration state. Then, heart rate monitor was attached on the body. Subjects were asked to rest for 10 min before data collection. After that, subjects performed tennis skill test using the modified Loughborough tennis skill test (mLTST). Service (left and right 10 balls each) and groundstroke (forehand and backhands 10 balls each) accuracy scores were recorded. The skill test was performed before and after simulated match. HR, RPE, TSS, and intestinal temperature were recorded during the first 30 seconds of 90 seconds break at the odd number of games: 1, 3, 5, 7, 9, and 11 during simulated tennis match. In addition, experiment was conducted within the same time of the day. Ambient temperature and humidity were recorded for each trial.

Statistical analysis

Two-way analysis of variance (ANOVA) with repeated measures was used to test significance main effects of cooling (DHRC Vs N-DHRC) and recovery time (game 3, 5, 7, 9, and 11). A paired *t*-test was used to establish if there were any significant differences in pre- and post-test simulated match.

The Wilcoxon matched pairs signed ranks test was also applied to the skill test data where normal distribution was not met. Data are present as mean standard error (x□ ±SEM) unless otherwise stated. Statistical significance was set at $p < 0.05$.

RESULTS

The physical characteristics are shown in Table 1.

Table 1 Characteristics of male tennis players (n=12). Values are means and standard deviations.

Variable	Mean ± SD
Age (yr)	21.75±2.3
Height (cm)	174.0±5.1
Weight (kg)	66.72±4.9
BMI	19.04±1.2
Body fat (%)	16.03±5.1
Resting HR (beat/min)	69.0±1.7
VO_{2max} (ml/kg/min)	48.95±4.3

The wet bulb globe temperatures (WBGTs) and relative humidity during the two experimental trials were not different; average temperature were (mean ± SD: WBGT = 31.01±0.30°C and 31.41±0.25 °C in DHRC and N-DHRC, respectively; average relative humidity were 59.9±1.61% *Vs.* 60.8±1.06%, in respectively). In DHRC, resting intestinal temperature (C°) after the first game were 37.28±0.04 and 37.55±0.04 °C, respectively and in N-DHRC, intestinal temperature were 37.31±0.04, and 37.65±0.06°C, respectively (Fig.1) There was no significant difference of intestinal temperatures at rest and during simulated match between DHRC and N-DHRC. During simulated tennis match (3^{rd} – 11^{th} game), intestinal temperatures were ranged between 37.64 - 37.96°C in DHRC, and37.72 - 38.22 °C in N-DHRC. A significant main effect of palms cooling (DHRC and N-DHRC trials) [$F(1.00, 11.00) = 5.52$, $p<0.05$] was found. There was a main effect of number of games during simulated tennis match [$F(2.04, 22.41) = 261.48$, $p<0.001$] and significant interaction between palms cooling and games [$F(1.93, 21.27) = 9.39$, $p<0.05$].

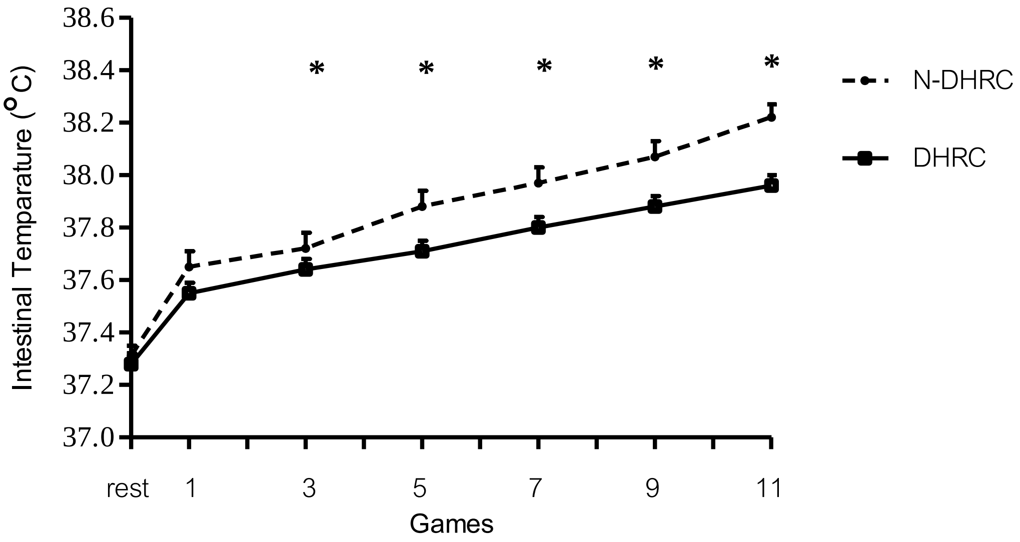

Fig 1. Intestinal temperatures (c°) during simulated tennis match between DHRC and N-DHRC group. Values are mean and SEM.

* Significant main effect of palms cooling, $p<0.05$.

Heart rate

There were not significantly different of heart rate between N-DHRC and DHRC at rest and at the first game (Fig.2). Resting HR and HR at the first game were 69±0.5 *Vs.* 68±0.5 bpm, and 138±0.9 *Vs.* 137±1.0 beats/min, respectively in DHRC and N-DHRC. During simulated tennis match (3^{rd} – 11^{th} games), HR were ranged 148 ± 0.88 - 176 ± 0.77 bpm in DHRC and between151±1.1 - 184±1.0 bpm in N-DHRC. HR in DHRC condition was lower than in N-DHRC condition ($p<0.001$). There was a main effect of number of game during simulated tennis ($p<0.001$). Additionally, a significant interaction between palms cooling and games ($p<0.001$) was observed, with a slower increase of HR in DHRC compared with N-DHRC.

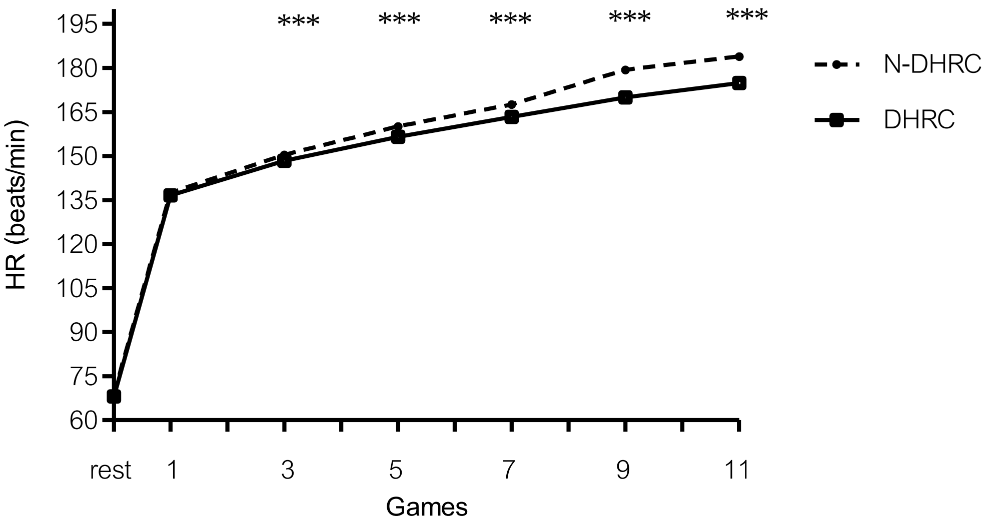

Fig 2. Heart rate (bpm) at rest and during simulated tennis match in DHRC and N-DHRC trials. Values are mean and SEM.

*** Significant difference between two trials at $p<0.001$.

Tennis skill test

The accuracy scores of service and ground stroke in the modified Loughborough tennis skill tests before and after the simulated match of both experimental trials were shown in table 2. There was no significant main effects of trials (N-DHRC and DHRC) and time on service [F (1, 11) = 0.11, *p*□0.05] and ground stroke [F (1, 11) = 1.34, *p*□0.05] accuracy scores. However, a significant interaction between palm cooling and games on ground stroke accuracy [F (1, 11) = 8.78, $p<0.05$] was found with a better score in DHRC.

Table 2. The accuracy scores (mean ± SEM) of services and ground stroke before and after the simulated game in DHRC and N-DHRC trials

Scores (out of 20 points)	N-DHRC		DHRC		Main effects (p-value)		Interaction (p-value)
Skills	Before	After	Before	After	Trial	Time	Interaction
Service (20)	8.1±1.05	7.5±0.97	8.8±0.59	9.9±0.57	0.744	0.071	0.336
Gs (20)	4.7±0.66	4.0±0.64	4.2±0.59	6.6±0.51	0.272	0.099	0.013*

Gs; ground stroke (forehand ground stroke + backhand ground stroke)

* Significant interaction (trial*time) effect, $p<0.05$

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Subjective evaluation

The medians and ranges of TSS and RPE during the simulated tennis match are shown in Table 3. Since normal distributions of the data were not met, Wilcoxon signed rank tests were used to test significant differences of TSS and RPE between DHRC and N-DHRC. There were significant differences on TSS following the 1st to the 9th games. Median values of TSS of DHRC were lower than those of N-DHRC.

Wilcoxon signed rank test showed a significant difference in RPE during the simulated tennis match as compared between N-DHRC and DHRC trial following play of the 7th, 9th, 11th (p<0.01) games.

Table 3. Thermal sensation scale (TSS) and rating of perceived exertion (RPE) during the simulated tennis match of N-DHRC and DHRC trials. Values are medians and ranges.

Subjective evaluation	TSS		RPE	
Time	N-DHRC	DHRC	N-DHRC	DHRC
Game 1	9 (7-9)	7* (6-10)	13 (11-14)	12 (12-14)
Game 3	9 (8-10)	8* (7-10)	14 (13-15)	13.5 (13-14)
Game 5	10 (9-10)	9* (7-10)	15 (14-16)	14.5 (14-16)
Game 7	10 (9-11)	9* (8-11)	16.5 (15-17)	15.5** (14-17)
Game 9	11 (10-12)	9.5* (8-12)	18 (16-18)	16** (15-17)
Game 11	11 (10-12)	10 (9-12)	18 (17-18)	17** (16-18)

*Significant difference between N-DHRC and DHRC conditions at p<0.05

**Significant difference between N-DHRC and DHRC conditions at p<0.01

DISCUSSION

In the current study, DHRC improved physiological responses and performances in male tennis players in the simulated tennis match. The DHRC group had lower intestinal temperature, HR and RPE than the N-DHRC group. These results revealed that using Double hand rapid cooling device had better heat tolerance than without Double hand rapid cooling device.

Intestinal temperature

DHRC device group showed decreasing in heat stress during exercise in tennis players resulting from lower core temperature changes from resting throughout experiment. These results suggested that extracting heat through the palm may provide an effective way to manipulate core temperature[13]. Yang *et, al.* (2009) found that this cooling device resulted in significantly lower rectal temperature compared with passive cooling. Reduction in heat storage enhances human safety and performance in hot environments.

Heart rate

The lower heart rate observed in DHRC could be the resulted of lower core temperature since the frequency of heart beat or firing rate of SA node are temperature-dependent[3]. Additionally, an increase in heat load during exercise especially in N-DHRC might lead to a greater activation of heat loss via increasing of cutaneous blood flow, and sweat rate which can compromise blood volume, venous return, left ventricular end-diastolic volume and stroke volume[20]. The drop in stroke volume was compensated by an increase in heart rate[16]. In contrast, in DHRC or palm cooling trial, heat loss via conduction and convective heat transfer by the blood were included. Then, the blood that has already been cooled down was sent to the body core via venous blood return. The beneficial effects of a similar cooling device in extracting heat from the body and lower heart rate have been shown[10]. The decrease of core temperature during simulated tennis play in the present study has also been found in the DHRC trial where cooling device was applied during recovery. Although, total sweat loss and sweat rate were not measured in the present study, it was possible that sweat loss might be greater in the N-DHRC trial. And the results of HR lower skin temp have increased heat transfer form core to skin temperatures via the effect of sweat evaporation.

The accuracy scores

In DHRC condition the accuracy scores were higher than those of N-DHRC condition. Cooling method via DHRC may help improving performance by making more blood available to serve working muscle instead of sending to body skin for reducing heat accumulation. Agree with Chaunchaiyakul *et, al.* (2012) showed that using double hand rapid cooling method during 30-sec recovery period, can improve anaerobic peak power and averaged anaerobic power as well as delay anaerobic power dropping in wrestler athletes particularly on the subsequent bout, supporting the benefits of intermittent cooling during exercise in attenuating fatigue[17].

Rating of perceived exertion (RPE)

An increase of RPE in DHRC condition (RPE≈ 9-11) was slower than N-DHRC condition (RPE ≈ 8-11). Similar findings was reported by March and Sleivert who cooled the upper body of elite cyclists before a single 70 sec bout of intense cycle exercise designed to mimic the 1000-m time trial. Cooling significantly lowered core temperature and RPE during warm-up and improved mean power output during the 70 sec test. Cooling may increase peripheral vasoconstriction of cooled regions, allowing increased blood flow to the working muscles[23]. Additionally cooling during exercise may relieve the feelings of thirst and provide a general perception that the exercise load is easier.

Thermal sensation scales

Thermal sensation scales (TSS; 1-13) during simulated tennis match in N-DHRC were significantly higher than DHRC. Although, the TSS was increased throughout the exercise time, a slower increased in the thermal sensation scales was observed in DHRC. The latter values are similar to those reported for able-bodied during arm crank ergometer in hot condition 32°C, 50 relative humidity[22]. Wearing the ice vest during exercise in the heat also delayed the increase in perceptions of thermal strain by 2 min compared with Pre cooling. It is likely that both the reduced thermal and cardiovascular strain contributed to the reduced perception of effort during the cooling trials.

CONCLUSION

Applying Palm cooling during 1-min rest between games shows benefits on thermoregulation and cardiovascular response during repeated games of tennis. The results of this study are not just to improve athletic performance in tennis athletes during competition but also include other competitive intermittent sports. We suggest that this specific local cooling can maintain some physiologic effect during intermittent sports and this technique offers better thermoregulatory changes during repeated exercise or competition. In addition, DHRC has also improved tennis performance. Therefore, DHRC might have positive effect on other competitive intermittent sports.

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