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Original research

Optimal cooling strategies for players in Australian Tennis Open conditions

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ABSTRACT

Objectives: We compared the utility of four cooling interventions for reducing heat strain during simulated tennis match-play in an environment representative of the peak conditions possible at the Australian Open (45 °C, <10% RH, 475 W/m^2 solar radiation).
Design: Nine trained males undertook four trials in a climate chamber, each time completing 4 sets of simulated match-play.
Methods: During ITF-mandated breaks (90-s between odd-numbered games; 120-s between sets), either iced towels (ICE), an electric fan (FAN_{dry}), a fan with moisture applied to the skin (FAN_{wet}), or ad libitum 10 °C water ingestion only (CON) was administered. Rectal temperature (T_{re}), mean skin temperature (T_{sk}), heart rate (HR), thermal sensation (TS), perceived exertion (RPE) and whole body sweating (WBSR) were measured.
Results: After set 3, T_{re} was lower in ICE (38.2 ± 0.3 °C) compared to FAN_{dry} (38.7 ± 0.5 °C; $p = 0.02$) and CON (38.5 ± 0.5 °C; $p = 0.05$), while T_{re} in FAN_{wet} (38.2 ± 0.3 °C) was lower than FAN_{dry} ($p = 0.05$). End-exercise T_{re} was lower in ICE (38.1 ± 0.3 °C) and FAN_{wet} (38.2 ± 0.4 °C) than FAN_{dry} (38.9 ± 0.7 °C; $p < 0.04$) and CON (38.8 ± 0.5 °C; $p < 0.04$). T_{sk} for ICE (35.3 ± 0.8 °C) was lower than all conditions, and T_{sk} for FAN_{wet} (36.6 ± 1.1 °C) was lower than FAN_{dry} (38.1 ± 1.3 °C; $p < 0.05$). TS for ICE and FAN_{wet} were lower than CON and FAN_{dry} ($p < 0.05$). HR was suppressed in ICE and FAN_{wet} relative to CON and FAN_{dry} ($p < 0.05$). WBSR was greater in FAN_{dry} compared to FAN_{wet} ($p < 0.01$) and ICE ($p < 0.001$).
Conclusions: Fan use must be used with skin wetting to be effective in hot/dry conditions. This strategy and the currently recommended ICE intervention both reduced T_{re} by ~0.5–0.6 °C and T_{sk} by ~1.0–1.5 °C while mitigating rises in HR and TS.

1. Introduction

Tennis is an intermittently high intensity sport often played in hot climates, with a significant risk of heat-related illness.[1] This problem was most evident during the 2014 Australian Tennis Open when ambient temperatures peaked at 44 °C, leading to the implementation of their extreme heat policy. A key aspect of this policy was the widespread use of various cooling interventions to mitigate thermal strain during mandated rest periods in match-play between odd-numbered games and between sets.[2] Specifically, ice wrapped in damp towels (ice towels) placed over the head, lap and around the neck are the currently recommended strategy for professional players (Personal communication: Elaine Brady, WTA; May 2015).

The application of ice towels may cool the skin, potentially lowering thermal sensation and improving perceived exertion.[5] However, towels present a barrier to sweat evaporation and skin cooling may cause local vasoconstriction,[6] despite elevations in core temperatures. On extremely hot days, when air temperature (T_a) far exceeds skin temperature (e.g. T_a: 45 °C), supplemental air flow across the skin with devices such as electric fans may increase the amount of heat added to the body via dry heat transfer (convection). But, the evaporation of sweat can be promoted to a far greater degree with the same increase in air flow.[7] Yet, due to the low ambient humidity (<10% RH) typically present at the Australian Open, sweat readily evaporates anyway, meaning greater air flow across the skin may provide no additional evaporation and potentially lead to a greater rise in core temperature due to the additional

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heat gain via convection—unless extra moisture is applied to the skin (e.g. with a damp sponge).[8]

While core temperatures of >39.0 °C have been reported during live professional tennis match-play,[3] to our knowledge only one study has assessed the impact of these different cooling interventions on physiological and perceptual heat strain in a tennis-related context. Specifically, either ice towels or fan use with additional moisture applied to the skin effectively mitigate elevations in thermal and cardiovascular strain in a warm/humid (36 °C, 50% RH) environment.[4] However, due to the aforementioned modifying effect of environmental conditions on evaporative and convective heat transfer, these findings cannot be directly translated to a very hot/dry setting.

Therefore, we compared the efficacy of (i) ice towels (ICE), (ii) electric fan use (FAN_{dry}), (iii) electric fan use with supplemental moisture applied to the skin (FAN_{wet}), and (iv) ad libitum 10 °C water ingestion only (CON), for reducing physiological and perceptual thermal strain during simulated tennis match-play in hot/dry conditions (45 °C, <10% RH). It was hypothesized that thermal and perceptual strain would be lower with FAN_{wet} and ICE compared to CON and FAN_{dry}, but athletes would be (and feel) coolest with FAN_{wet} and hottest with FAN_{dry}.

2. Methods

Nine male recreational athletes (22 ± 3 years; 179 ± 5 cm; 73.9 ± 5 kg; peak oxygen consumption (VO_{2peak}): 51.7 ± 4.6 ml/kg/min; body fat: 12.0 ± 4.7%) free from cardiovascular and metabolic health disorders were recruited for the study. VO_{2peak} inclusion criteria aligned with the existing literature on elite tennis players.[9] Participants did not consume caffeine or alcohol nor partake in strenuous exercise 24-h prior to testing. Approval was obtained from The University of Sydney Human Research Ethics Committee (HREC#:2015/420) and written informed consent was acquired from all participants.

Rectal temperature (T_{re}) was measured with a general-purpose paediatric thermistor probe (TM400, Covidien, Mansfield, MA, USA) inserted to a depth of 15 cm past the anal sphincter. Mean skin temperature (T_{sk}) was estimated using a weighted mean of chest, shoulder, thigh, and calf skin temperatures[10] with wireless temperature sensors (iButtonDS1921H-F5, Embedded Data Systems, USA) secured to the skin surface using surgical tape (e.g. Transpore, 3M, Canada). Heart rate (HR) was measured with a monitor placed around the chest (Polar RS400, Kempele, Finland). Whole body sweat rate (WBSR) was estimated from pre- and post-trial body mass measurements (±2 g) using a platform scale (Mettler, Germany), corrected for weight gain through fluid ingestion.

Thermal sensation (TS) was measured with a modified ASHRAE visual analogue scale, previously validated for use in physiological applications.[11] Each participant marked the scale ranging from "very cold" to "very hot" (0–200 mm) immediately before and after each break when interventions were applied, and again at the end of the following simulated game. The rating of perceived exertion (RPE) was measured using a modified Borg scale[12] with standard increments of 6 to 20, but with participants instructed to answer the specific question: "How easy is it to continue this exercise?" Values were measured before and after each break.

In a preliminary trial, participants completed a Physical Activity Readiness Questionnaire (PAR-Q) and an American Heart Association Screening Questionnaire. Their body mass, height, and VO_{2peak} were measured. Additionally, mean VO_2 over the course of five simulated games of tennis match-play [see *Experimental Protocol*] was assessed to ensure that VO_2 (26.7 ± 1.7 ml/kg/min), as well as relative intensity (~52% VO_{2peak}), during the experimental protocol were comparable to tennis match-play on the same surface as the Australian Open (VO_2: 27.5 ml/kg/min[13]; %VO_{2peak}: ~55%[14,15]). VO_{2peak} and mean VO_2 were measured using a metabolic cart (COSMED, Quark CPET, Italy) on a treadmill (h/p cosmos Saturn 300/125, Germany). VO_{2peak} was assessed following the protocol of the Canadian Society of Exercise Physiology.[16] In addition, body fat

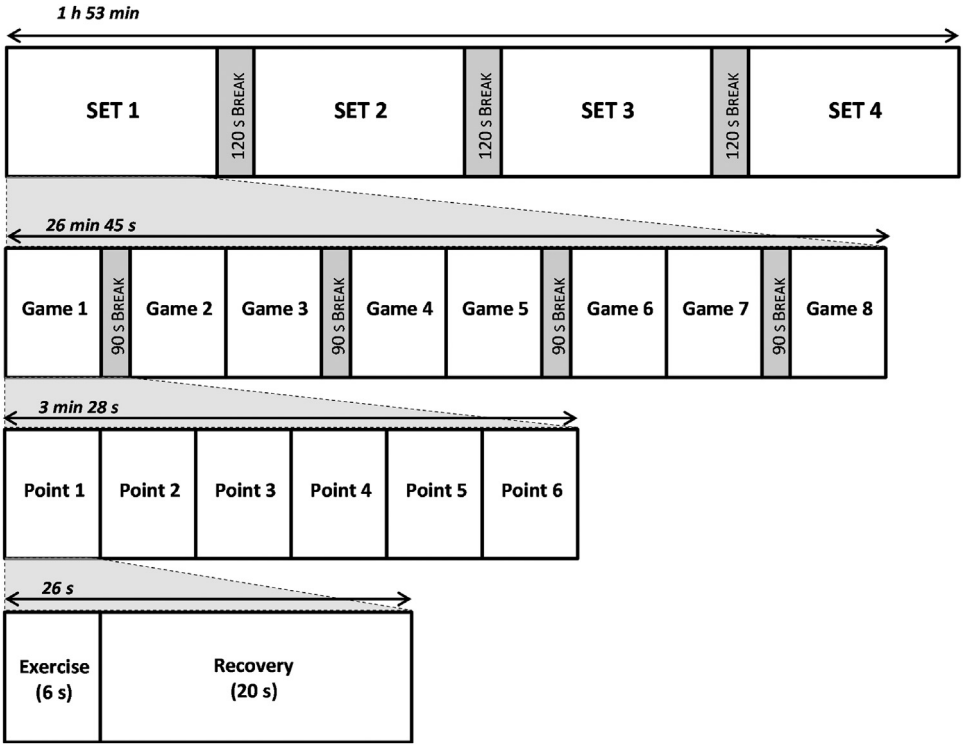

Fig. 1. Schematic illustrating the breakdown of the protocol to simulate four sets of tennis match-play. Each set consisted of eight games, with a 120-s break between sets and a 90-s break upon the completion of each odd-numbered game. Each game consisted of six identical points comprised of 6 s of high intensity exercise and 20 s of recovery.