

# POST-EXERCISE COOLING TECHNIQUES IN HOT, HUMID CONDITIONS

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## INTRODUCTION

Many major sporting events occur in environments that would be regarded as thermally stressful from the perspective of heat. This trend continued at the recent summer Olympics in Beijing, which were held when climatic conditions were typically 31°C, 70%RH, giving a risk of heat illness that is moderate to high. At the extreme, heat stroke is a serious medical condition resulting in collapse. Less severe heat strain increases the cardiovascular load associated with exercise, diminishes the drive to exercise, compromises muscle and hepatic blood flow, increases muscle glycogen utilisation and results in slower performance times, and earlier fatigue (Rowell et al. 1966). Therefore, during competition it is important to delay the onset of heat strain and to enhance body cooling during rest periods in sports which have defined breaks.

It is generally accepted that the optimal cooling strategy in hyperthermic persons is whole body cold water immersion (CWI) (Smith 2005). However, this is not logistically feasible when breaks between halves or events are short. Techniques for achieving artificial cooling typically utilise smaller body surface areas than that covered during CWI and include: ice vests or phase change garments (PCG; Duffield et al 2003), jackets or caps (conductive cooling) (Armstrong et al. 1995); air cooled garments (ACG) or fans (convective/evaporative cooling; Chinevere et al. 2008), hand immersion (HI: conductive cooling; House et al. 2003) and liquid-cooled garments (LCG, conductive cooling).

The present experiment was designed to assess the effectiveness of different cooling techniques at rest following exercise. The cooling periods were similar to those experienced in halftime breaks or intervals. A wide range of cooling techniques commercially available at the time were examined and deployed as per the manufacturers' instructions. Each was tested with and without the presence of face-fanning. It was hypothesised that all of the cooling methods would result in faster cooling than that measured in a natural (passive) cooling control condition, with hand immersion being the most effective based on evidence from military based studies. It was also hypothesised that the addition of face fanning would improve thermal comfort.

## METHODS

*Participants:* The protocol was approved by the University of Portsmouth Ethics Committee. Having provided written informed consent and having completed a medical examination, nine males (age 22 [3]years; height 1.80 [0.04]m; mass 69.80 [7.10]kg; surface area 1.90 [0.10]m<sup>2</sup>; sum of skinfolds 34.0 [14.0] mm; body fat 14.4 [4.4]%) volunteered to participate.

*Procedure:* The study used a within participant repeated measures design in which participants completed self-paced exercise on a treadmill in hot (31.20 [0.20]°C) and humid (70 [1.90] % RH) conditions until they reached a rectal temperature of 38.5°C. They then received one of five post-exercise cooling techniques or completed a control condition for 15-minutes (COOL 1). At the end of COOL1 participants recommenced self-paced exercise until their deep body temperature again reached 38.5°C. They then completed a 30-minute period of post-exercise cooling using the same cooling intervention as COOL1, but with (COOL 2A 0-15 minutes) and without (COOL 2B 15-30 minutes) the addition of face fanning. The order of exposure to cooling

manipulations was counter-balanced using a Latin Square and the treatment conditions were as follows:

*Control Condition (CON)*: Each participant sat and rested and did not receive any active cooling.

*Hand Immersion (HI)*: Each participant rested and immersed their hands into a water bath filled with cool tap water ( $\sim 17^{\circ}\text{C}$ ) to the level of the wrist (radial notch). Water temperature ( $T_w$ ) during HI was  $17.80 [0.70]^{\circ}\text{C}$  in COOL 1,  $16.40 [0.50]^{\circ}\text{C}$  in COOL 2A and  $16.40 [0.50]^{\circ}\text{C}$  in COOL 2B.

*Phase Change Garment (PCG)*: Each participant donned a vest-styled garment containing two cooling packs inserted into the front and rear of the vest. At temperatures above  $10^{\circ}\text{C}$  the contents of the panel inserts (long chain alkanes) melt and extract heat ( $211.7 \text{ kJ.kg}^{-1}$ ), via conduction. The surface area covered by the PCG was  $\sim 0.40\text{m}^2$ .

*Air cooled garment (ACG)*: Each participant donned a torso-covering vest secured in place using Velcro straps. During cooling both fans, situated front and back, were switched on simultaneously distributing ambient air around the vest at a rate of  $180 \text{ L}\cdot\text{min}^{-1}$  through a spacer mesh integrated vented system to the torso. The surface area covered by the ACG was  $\sim 0.34\text{m}^2$ .

*Liquid Cooled Garment (LCG)*: Participants donned a vest secured in place by a zip at the front of the garment. At the start of the cooling period the battery operated cooling system was switched on and pumped saline ( $\sim 500\text{mL}$ ) cooled by an ice pack around a series (24 tubes, 12 parallel channels) of inter-connected tubes. When saline temperature of  $>12.3^{\circ}\text{C}$  is reached the thermostat directs the circulating saline through the ice pack. The surface area covered by the LCG was  $\sim 0.40\text{m}^2$ .

*Whole body fanning (WBF)*: Participants were seated in front of fan blowing ambient air at a speed of  $3.5$  to  $3.80 \text{ m}\cdot\text{s}^{-1}$  onto the torso, arms and legs of the participant. Throughout all conditions, including CON, the head of the participant was isolated from the fan airflow by a flexible mat.

*Face Fanning*: Air was directed at the face only at a speed of  $2$ - $2.5\text{m}\cdot\text{s}^{-1}$ . The face fan was switched off at the start of COOL 2B; a perceptual measure was taken 1-minute after the fan was switched off. At the end of the second cooling bout (COOL 2B; 15-30 minutes) participants left the environmental chamber and were cooled by seated tepid showering.

*Measurements*: Fluid was consumed *ad libitum* throughout the study and was recorded using digital weighing scales. Fluid intake and pre and post naked and clothed body weights were used to estimate sweat production. Deep body temperature was measured with a calibrated rectal thermistor ( $T_{re}$ ) inserted 15cm beyond the anal sphincter. Skin temperature ( $T_{sk}$ ) was measured using thermistors attached to the skin by tape at four sites: chest, arm, thigh and calf (Ramanathan 1964).  $T_{re}$  and  $T_{sk}$  were recorded each minute on a data logger. Skin blood flow (SkBf) was measured using laser Doppler flowmetry probes attached to the index finger of the right hand. Perceptual measures of thermal comfort (TC) were taken every 5 minutes using a perceptual scale ranging from Very Uncomfortable (0cm); Uncomfortable; Just Uncomfortable; Just Comfortable, Comfortable; Very Comfortable (20cm).

Calculations: Mean skin temperature ( $T_{msk}$ ) was calculated according to the formula:  $T_{msk} = 0.3 (T_{chest} + T_{arm}) + 0.2 (T_{thigh} + T_{calf})$  (Ramanathan 1964)

Mean body temperature ( $T_b$ ):  $T_b = 0.8T_{re} + 0.2T_{msk}$  (Colin et al. 1971)

Stored heat (S) was calculated for each 15 minute cooling period:  $S = (\Delta T_b \times 3.48 \times \text{mass})/t$   
The average specific heat of body tissues was assumed as  $3.48\text{kJ}\cdot\text{kg}^{-1}\cdot\text{C}^{-1}$  (Pembrey 1898)

*Data Analyses:* Multivariate Analysis of Variance (MANOVA) with repeated measures was used to examine for differences between cooling manipulations in rate of temperature change, cooling power, SkBf, sweat responses and TC within and between COOL1, COOL 2A and COOL 2B. Assumptions of sphericity were checked using Mauchley's test and adjustments were made accordingly (Greenhouse-Geisser). The presence of statistically significant effects were determined using a *post-hoc* pairwise comparisons procedure. TC was also examined before, 1 minute following and 5 minutes following the switching off of the face fan (RM-ANOVA). The alpha level for all statistical tests was set at 0.05. Data are presented as mean [s.d].  $P > 0.05$  denotes no significant difference. The observed power, where the chance of type II error is equal to  $1 - \beta$ , is reported following each significant finding denoted by  $\beta$ .

## RESULTS

During exercise period 1 the average rate of rise in  $T_{re}$  was  $5.33\text{C}\cdot\text{h}^{-1}$  ( $N = 54$ ); all participants had reached a  $T_{re}$  of  $38.5\text{C}$  by the 25<sup>th</sup> minute of exercise. Differences between cooling manipulations based on  $T_{re}$ , heat loss and SkBf are summarised in figures 1, 2 and 3 respectively. Statistical findings are presented in the following format, **WBF**>CON and indicates cooling power of **WBF** is greater than (>) CON. Only the significant effects are reported.

There were no significant differences in sweat produced or fluid consumed between conditions ( $P > 0.05$ ), the average across all conditions was: fluid consumed 792 [262]mL and sweat produced 1001 [210]mL. Sweat evaporated differed significantly between conditions ( $P = 0.008$ ;  $\beta = 0.888$ ) showing that significantly more sweat was evaporated in the **WBF** (90.40 [6.00]%) than the CON only (73.90 [11.00]%); ACG (82.20 [4.00]%; LCG (84.00 [6.00]%; HI (83.00 [6.00]%; PCG (82.80 [5.00]%).

No significant differences were evident between individual cooling conditions in mean TC rating in COOL 2A (face fanning) versus COOL 1. Mean ratings were COOL 1: 10.8 [0.8] - *just comfortable*; COOL 2A 12.2 [0.6] - *just comfortable to comfortable*; COOL 2B 13.4 [0.6] - *just comfortable to comfortable*; differences between COOL 1 (no face fanning) and COOL 2A (face fanning) neared significance ( $P = 0.077$ ). After switching off the fan, participants reported being more comfortable ( $P = 0.003$ ;  $\beta = 0.978$ ) in the HI and PCG conditions than in the CON.

Between cooling periods  $T_{re}$  ( $P = 0.001$ ;  $\beta = 0.999$ ),  $T_{msk}$  ( $P = 0.002$ ;  $\beta = 0.951$ ) and  $T_b$  ( $P = 0.002$ ;  $\beta = 0.950$ ) reduced at a faster rate in COOL 2A (with face fanning) than in either COOL 1 or COOL 2B.

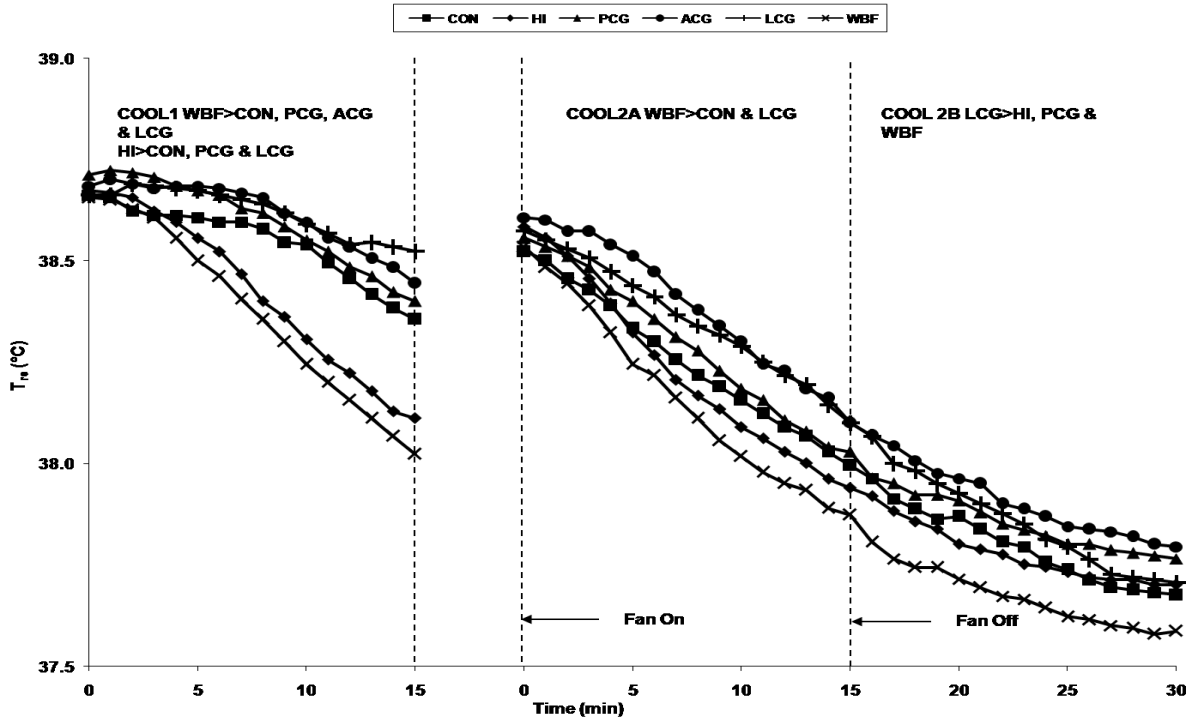


Fig 1. Mean  $T_{re}$  changes across conditions during COOL 1, 2A and 2B (n=9).

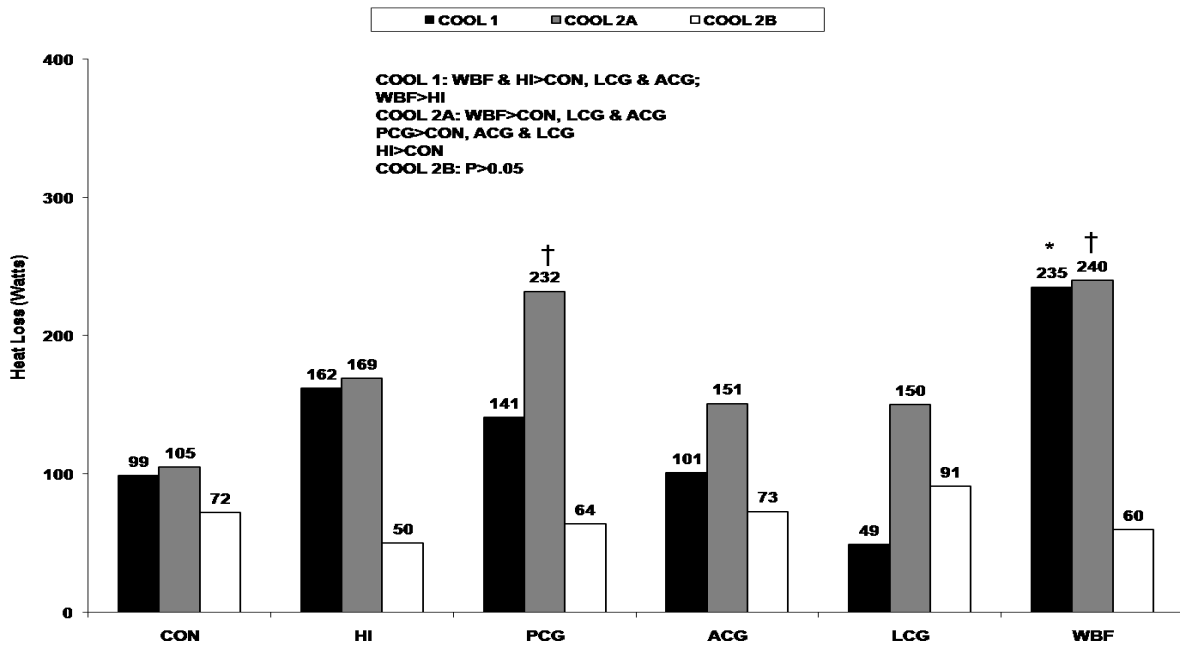
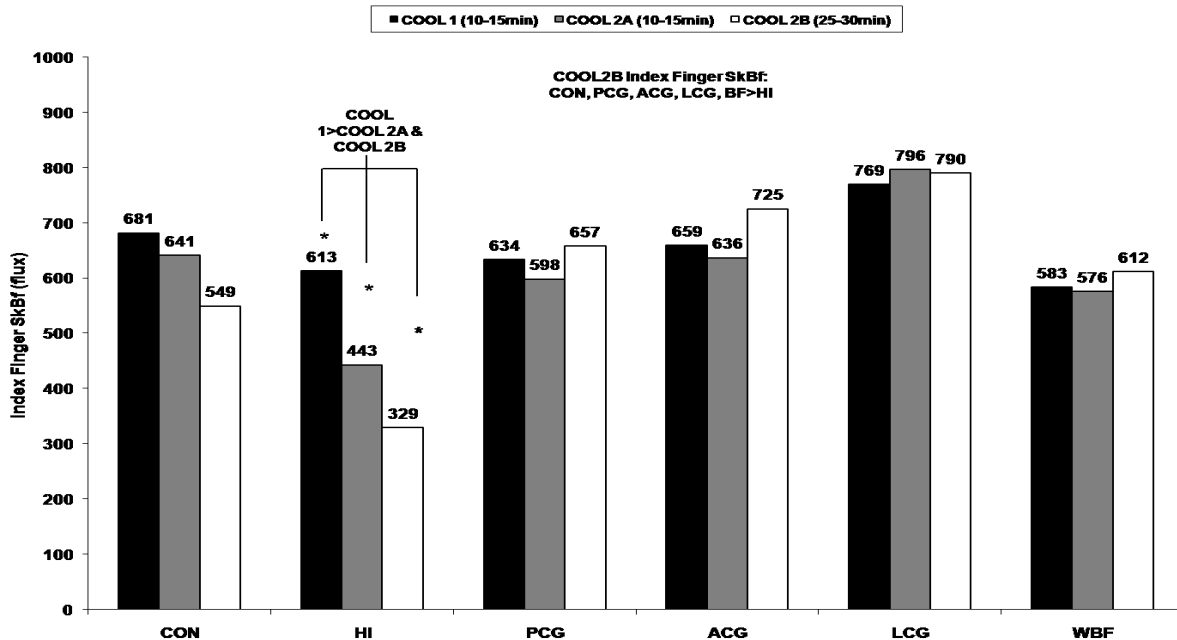


Fig 2. Mean cooling power of each cooling intervention in COOL 1, COOL 2A and 2B (n=9); (\*) denotes greater cooling power in COOL 1 and COOL 2A (†).



**Fig 3.** SkBf across conditions in the last 5 minutes of COOL 1, 2A and 2B (n= 9).

## CONCLUSIONS

This study examined the efficacy of five post-exercise cooling techniques in conditions that pose a significant risk of heat-illness during exercise, in participants wearing athletic clothing and for a duration similar to that allocated between sporting events or halves; the findings could be applied to a variety of sports. The data show the most effective form of cooling was body fanning. Phase change chemical blended inserts were effective in cooling the skin, but had a less substantial effect upon deep body temperature. The remainder of the cooling interventions examined in this study were generally statistically indistinguishable from the control condition. When the drop in rectal temperature was examined, hand immersion closely reflected the cooling power of body fanning providing only partial support for the experimental hypothesis. It is concluded that when time for cooling is short, those techniques that enhance physiological cooling mechanisms (WBF & HI) produce rapid initial drops in body temperature.

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