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ORIGINAL ARTICLE

Effects of a cooling collar on affect, ratings of perceived exertion, and running performance in the heat

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Abstract

During prolonged exercise, ratings of perceived exertion (RPE) and affect (pleasure; activation) play an important role in performance, especially in hot conditions. Although various mechanisms have been tried to manage the effects of heat (e.g. cooling jackets), the purpose of the current research was to assess the effect of a cooling collar on RPE, affect, thermal sensation, and running performance in the heat. Participants ($n = 8$) wore a cold collar, uncooled collar or no collar as they completed three 90-min preloaded treadmill time-trials in the heat ($30.5 \pm 0.1^\circ\text{C}$), which included 75 min at $\sim 60\% \dot{V}\text{O}_{2\text{max}}$ followed by a 15-min time-trial. Affect, RPE, and thermal sensation were measured throughout. Performance during the time-trial was significantly improved in the cold collar compared with the uncooled collar and no-collar trials; however, pleasure and activation ratings were highest for the no-collar trial. Findings suggest that a cooling collar may improve performance, but not necessarily “feel good”. Practically, it seems necessary to ensure sufficient education about the benefits, on balance, of the cold collar, while the performance improvements outweighed the reported discomfort of athletes in this study. In addition, the cold collar may prove quite beneficial for individuals who work in hot climates and/or conditions, as it may be effective in minimizing discomfort associated with heat for other groups as well.

Keywords: *Psychophysiology, pleasure–displeasure, arousal, activation, perceived exertion*

Introduction

Exercise capacity (Galloway & Maughan, 1997) and performance (Tyler & Sunderland, 2008a) are both impaired in hot compared with moderate conditions. This impairment has been related to a central component that may either diminish the drive to exercise or change the pacing strategy of athletes during performance trials (Nybo & Nielsen, 2001b; Tucker, Rauch, Harley, & Noakes, 2004). Furthermore, research has shown that blood flow to the brain can be altered during exercise in the heat (Nybo, Moller, Volianitis, Nielsen, & Secher, 2002) and that perceived exertion may be related to altered brain activity (Nybo & Nielsen, 2001a). The attainment of high body ($\sim 40^\circ\text{C}$) and more likely brain temperatures ultimately limits exercise performance in the heat (Caputa, Feistkorn, & Jessen, 1986).

Some researchers have used resting frontal electroencephalographic asymmetry (as an individual difference measure of affective style) to assess, for example, its predictability for affective responses to exercise at three different intensities standardized relative to the ventilatory threshold (Hall, Ekkekakis, & Petruzzello, 2010), and also with healthy adolescents to explain variance in affective response during and after exercise at two different intensities (Schneider, Graham, Grant, King, & Cooper, 2009). However, the effect of high core temperatures and brain temperature on affect has not been studied. Given the obvious practical challenges associated with assessing, in particular, brain temperature during exercise, it is necessary and useful to consider a range of factors to better understand the psychophysiological processes related to exercising in the heat.

Material aids for prolonged physical performance in the heat

Recent research has highlighted the usefulness of pre-cooling to minimize the adverse affects of heat on prolonged performance (Duffield, Green, Castle, & Maxwell, 2010; Marino, 2002). For example, researchers have assessed the efficacy of cooling jackets on endurance performance in a warm environment (Hasegawa, Takatori, Komura, & Yamasaki, 2005), and compared pre-cooling techniques before competition in the heat (Quod, Martin, & Laursen, 2006) and their effects on cycling time-trial performance during warm conditions (Quod et al., 2008). Furthermore, cooling the neck via a cooling collar has been shown to improve both running capacity (Tyler & Sunderland, 2009) and performance in the heat (Tyler & Sunderland, 2008b). In general, findings have supported the usefulness of pre-cooling for endurance exercise in the heat, although there is some evidence to suggest that benefits are negligible for some types of exercise, such as intermittent exercise or that of short duration (Marino, 2002). Marino (2002) indicated in his review the benefits of pre-cooling include an enhanced capacity to store heat and an increase in time to exhaustion by way of reducing body temperature before exercise; thus, intermittent or short-duration exercise may be less affected by those benefits due to the differentiated demands of the body and related mechanisms associated with them compared with endurance exercise.

Material aids for prolonged physical and psychological performance

Other researchers have assessed the influence of carbohydrate (Backhouse, Ali, Biddle, & Williams, 2007a; Backhouse, Bishop, Biddle, & Williams, 2005) and water ingestion (Backhouse, Biddle, & Williams, 2007b) during prolonged exercise on affective states and perceived exertion, although these studies have not specifically been conducted under hot conditions. Backhouse et al. (2005) found that carbohydrate ingestion improved feelings of pleasure both during and after prolonged cycling bouts, and also found support for assessing *both* perceived exertion (“what” one feels as measured by Borg’s (1975) scale) and pleasure–displeasure (“how” one feels as measured by Hardy and Rejeski’s (1989) scale) (see below regarding assessment). Similarly, Backhouse et al. (2007b) found that ingesting water during prolonged, submaximal running helped to minimize the expected decrease in pleasure–displeasure during the task, and was also linked to improvement in subjective states following the task. In combination, these studies lend strong

support for investigating both physical and psychological aspects of performance.

Rationale for assessing prolonged physical and psychological performance in the heat

There are several major sporting events that are both conducted under hot conditions and involve prolonged participation (e.g. 2004 and 2008 Olympics, Formula One motor racing, and year-round warm weather sports such as cricket). Given that there is substantial evidence to show that heat impairs exercise capacity (Galloway & Maughan, 1997) and performance (Tyler et al., 2008a), that pre-cooling for endurance exercise can reduce the severity of such impairment (Duffield et al., 2010; Marino, 2002; Nybo, 2007), and that physical and psychological factors are both important to performance (Backhouse et al., 2005, 2007a, 2007b; Bixby & Lochbaum, 2006; Cheung, 2007), there is merit in conducting research that addresses a range of relevant factors to better understand the psychophysiological processes related to exercising in the heat. Thus, a valuable extension of previous research would be to identify ways to support optimal physical and psychological preparations, as these two aspects are inextricably linked (Cheung, 2007).

Assessing psychological performance in an exercise environment

The rating of perceived exertion (RPE) is a useful measure to assess the social psychophysiological phenomenon of “what one feels” (Rejeski, 1985), but does not provide information about “how one feels” (Hardy & Rejeski, 1989). For example, the same perceived workload during exercise for two different individuals might reflect someone feeling extremely good or, just as likely, extremely poorly. Alongside the RPE scale, the use of two measures in particular has been supported in recent psychophysiological research to assess the subjective component of how individuals feel during exercise (Backhouse et al., 2007a). The Feeling Scale (Hardy & Rejeski, 1989) measures pleasure–displeasure, or how good or bad one feels, and Svebak and Murgatroyd’s (1985) Felt Arousal Scale (FAS) assesses how energized or activated (excited–bored) one feels. Key advantages to the scales are that they can be easily administered during exercise, and the two scales tap into different affective states and enable changes to be identified at different time points during bouts of prolonged exercise (Backhouse et al., 2007a).

Purpose of the research

There is a need to examine the use of external aids on performance in the heat. As affective changes have been shown to have a significant impact on outcome and task performance, it is important to measure affective states as well performance (Acevedo et al., 2007). It appears that this is best accomplished through a combination of the Feeling Scale, the Felt Arousal Scale, and perceived exertion (Backhouse et al., 2007a, 2007b). Therefore, the purpose of this study was to examine the impact of a cooling collar on running performance, affective state as measured by the Feeling Scale and Felt Arousal Scale, perceived exertion as measured by the RPE, and thermal sensation.

Methods

Participants

Eight healthy, trained males volunteered for the study. The mean ($\pm s$) age, body mass, height, and relative maximal oxygen uptake ($\dot{V}O_{2\max}$) of the eight participants was 25 ± 5 years, 77.4 ± 5.6 kg, 181.0 ± 7.8 cm, and 53.7 ± 4.7 mL $\cdot$ kg $^{-1}$ $\cdot$ min $^{-1}$, respectively. The participants were fully informed of any risks and discomforts associated with the study before providing oral and written informed consent to participate and completing a health screen. The health screen was repeated before each laboratory visit to ensure the health status of the participants. The study received approval from the institution's Ethics Advisory Committee.

Measures of affect, perceived exertion, and thermal sensation

The Feeling Scale (FS) is an 11-point bipolar measure of pleasure–displeasure (Hardy & Rejeski, 1989). The scale ranges from +5 (“good”) through 0 (“neutral”) to –5 (“very bad”). Face and content validity have been shown for the Feeling Scale (Hardy & Rejeski, 1989) and support has been provided for its construct validity (Kenney, Rejeski & Messier, 1987; Rejeski, Best, Griffith, & Kenney, 1987). The Felt Arousal Scale (FAS) is a 6-point measure of perceived activation/arousal and ranges from 1 (“low arousal”) to 6 (“high arousal”) (Svebak & Murgatroyd, 1985). [For further detail and information about the scale's psychometric properties, see Murgatroyd, Rushton, Apter, and Ray (1978).] Similar to previous research (e.g. Backhouse et al., 2007a), the Feeling Scale and Felt Arousal Scale were administered at baseline and then every 15 min during the pre-load and every 5 min during the time-trial. The RPE was also assessed every 5 min during the pre-load and every 2.5 min

during the time-trial (Borg, 1975). Thermal sensation was an overall rating and was assessed with an 8-point scale, ranging from 0 (“unbearably cold”) to 8 (“unbearably hot”) with 4 as comfortable (neutral) (Young, Sawka, Epstein, Decristofano, & Pandolf, 1987). Thermal sensation recordings were taken at baseline, every 5 min during the pre-load, and then every 2.5 min during the time-trial. The RPE scale was presented first, followed by the thermal sensation scale, then the Feeling Scale, and finally the Felt Arousal Scale.

Experimental design

Before the main trials, participants completed an incremental motorized treadmill test to determine $\dot{V}O_{2\max}$ following Jones and Doust (1996). Briefly, the protocol consists of two parts: in the first phase, athletes undertake a multi-stage incremental test to ascertain oxygen uptake, heart rate, and blood lactate responses at a range of training and racing speeds; in the second phase, athletes are instructed to put in a maximal effort and run for as long as possible. Following a full familiarization trial, the participants visited the laboratory on three occasions for the main experimental trials. The experimental trials were conducted at the same time of the day on each occasion ± 30 min and were separated by 7 days for all participants except one. Participant 7 completed his final trial after a one-month break (due to mechanical failure during his final trial); he was re-familiarized 7 days before the repeated final trial. The distance covered in the re-familiarization was within the established coefficient variation of the protocol (2.7%; Tyler et al., 2008a) compared with the initial familiarization trial, and so data for Participant 7 have been included. The outdoor temperature on the days of the main trials was $6.41 \pm 3.06^\circ\text{C}$.

During the familiarization and experimental trials, participants completed a 90-min pre-loaded time-trial in hot conditions ($30.4 \pm 0.1^\circ\text{C}$; $53 \pm 2\%$ relative humidity). The pre-loaded time-trial consisted of 75 min of treadmill running at $\sim 60\%$ $\dot{V}O_{2\max}$ (9.0 ± 1.1 km $\cdot$ h $^{-1}$) followed by a self-paced 15-min time-trial during which participants were instructed to cover as much distance as they could during the time, displayed via a countdown timer. The distance covered was not revealed until the completion of all trials.

During the three experimental trials, participants completed the pre-loaded time-trial while wearing a cold collar, an uncooled collar or no collar. The collar consisted of two parts and was modified from a commercially available neck-cooling device (Black Ice LLC, Lakeland, USA). The cooling section was made from a thin plastic polymer and consisted of

five compartments that were drained of the Black Ice cooling agent and filled with 120 g of gel refrigerant (BDH Laboratory Supplies, Poole, Dorset, UK). It was established during in-house pilot work (unpublished data) that the gel refrigerant provided the greatest cooling without tissue damage and so was used in this study to ensure that the assessed collar was as cold as it could be. The cooling section of the collar was held in place by a 600-mm neoprene wrap secured with Velcro fastenings at the anterior aspect of the neck. The dimensions of the cooling section of the collar were 375 mm (length) $\times$ 60 mm (width) $\times$ 15 mm (depth) and it weighed 155 g when dry at room temperature. For the cold collar trials, the collar was frozen for 24–28 h in an industrial freezer at -80°C and was then left in ambient conditions for 5 min and cleared of any surface frost prior to application. For the uncooled collar trials, the collar was kept at ambient laboratory temperature for at least 24 h before application.

The trials were conducted in a randomized and counterbalanced order. Blinding the trials was impossible and so in an attempt to prevent any related problems, participants were given information regarding why the collar could improve or impair performance and the investigator was careful not to give any information regarding his opinion of the effectiveness of such an intervention.

Experimental procedures

Participants abstained from alcohol and caffeine and completed a food record for the day prior to the initial experimental trial. They adopted the same diet and abstained from strenuous exercise for 24 h before each main trial. Participants arrived at the laboratory ~ 30 min before the start of the trial in a fasted (≥ 10 h post-prandial) state and having ingested 500 ml of water ~ 1.5 h previously. On arrival, nude body mass was recorded. A rectal probe (Grant Instruments (Cambridge) Ltd., UK) was self-inserted ~ 10 cm past the anal sphincter and a heart rate monitor (Polar Electro Oy, Kempele, Finland) was attached and an indwelling cannula (Venflon, Becton Dickinson UK Ltd., Oxford, UK) inserted into an antecubital vein before the participant entered the environmental chamber (Design Environmental WIR52-20HS, Design Environmental Ltd., Gwent, UK). The indwelling cannula was kept patent by an injection of saline (5 ml) after each sample. Participants rested in the environmental chamber in an upright position for 5 min, wearing the collar when appropriate (cold collar and uncooled collar), after which resting values for heart rate, rectal temperature, mean neck temperature, and thermal sensation were obtained. Mean neck temperature was calculated as the mean temperature

of four skin thermistors spaced equally across the anterior aspect of the neck. All thermistors were attached via a transparent dressing (Tagaderm, 3M Health Care, USA) and waterproof tape (Transpore, 3M Health Care, USA). Thermal sensation was rated with an 8-point scale, ranging from 0 (“unbearably cold”) to 8 (“unbearably hot”) with 4 as comfortable (“neutral”) (Young et al., 1987).

During the 75-min pre-load phase of the trials, heart rate, rectal temperature, mean neck temperature, and thermal sensation were recorded at 5-min intervals while $\dot{V}\text{O}_2$ was measured at 40 and 60 min via the Douglas bag method. During the time-trial, heart rate, rectal temperature, mean neck temperature, and thermal sensation were recorded at 2.5-min intervals, allowing for closer monitoring during the higher-demanding phase. Distances run during the 75-min pre-load phase and the subsequent 15-min time-trial were recorded. The mean self-selected speed for the time-trial was calculated from these data. Following the completion of each trial, participants towel-dried and recorded a dry post-exercise body mass from which sweat loss and the percentage change in body mass were calculated taking into account voluntary fluid consumption and any urinary excretion during the protocol.

Blood analyses

Consistent with previous psychophysiological research that has assessed a number of physiological parameters relevant to endurance exercise (Acevedo et al., 2007; Backhouse et al., 2005, 2007a; Rudolph & McAuley, 1998), selected blood analyses are reported here to provide a comprehensive picture that includes pertinent physiological measures. Specifically, whole blood was initially analysed in triplicate for lactate and glucose (2300 STAT plus, Yellow Springs Instruments Inc., Ohio, USA), haematocrit (Micocentrifugation, Hawksley, Sussex, UK), and haemoglobin (B-hemoglobin photometer, Hemocue AB, Angelholm, Sweden); aliquots were then dispensed into $\text{K}_3\text{-EDTA}$ tubes for the subsequent analysis of platelet-free plasma (Sarstedt Ltd., Leicester, UK). Samples were centrifuged at 3000 *g* for 15 min at 4°C . After centrifugation, the supernatant was removed and then frozen, initially at -20°C overnight in a vertical position before being frozen at -80°C until the analyses were performed. Plasma concentrations of cortisol were determined via enzyme-linked immunosorbent assay (DRG Instruments GmbH, Marburg, Germany).

Statistical analysis

Descriptive data are reported as means $\pm$ standard deviations (*s*). Given the exploratory nature of the

current investigation, data handling was conducted in two ways based on the main purpose of the research. First, a series of two-way (trial $\times$ time) repeated-measures analyses of variance (ANOVA) were performed to evaluate differences between trials with regard to performance (running distance), physiological responses and indices, affective states (pleasure–displeasure and perceived activation), RPE, and thermal sensation (referred to as “T90” in results below, as the time variable comprised data from 0 to 90 min, inclusive). Second, two-way repeated-measures ANOVAs were conducted to assess differences between the steady-state ($\sim 60\% \dot{V}O_{2\max}$; <75 min) and time-trial (all-out effort; 75 to 90 min) segments separately with respect to affect (pleasure–displeasure and perceived activation) and RPE measures (referred to as “steady state vs. time-trial” in results). Tukey *post-hoc* tests were conducted to assess differences between conditions. The effect size (d) of all significant differences was calculated (Cohen, 1988). Statistical significance was set at $P < 0.05$.

Results

Analyses indicated several noteworthy findings with respect to differences between performance outcomes, physiological parameters, and affective indices for the current study. Significant findings below reflect main effects unless otherwise specified.

Performance

Performance during the time-trial was improved by wearing a cold collar compared with both the no-collar and uncooled collar trials ($F_{2,14} = 11.7$, $P < 0.001$). Distance run during the time-trials was 2976 ± 489 , 2823 ± 579 , and 2674 ± 532 m for the cold collar, no-collar, and uncooled collar trials, respectively. Significantly more distance was covered in the cold collar than the uncooled collar ($P = 0.008$; $d = 0.56$) and no-collar trials ($P = 0.041$; $d = 0.28$). There was no significant difference in the distance covered in the no-collar and uncooled collar trials ($P = 0.079$; $d = 0.26$).

Physiological responses and indices

Responses: Oxygen uptake, $\% \dot{V}O_{2\max}$, heart rate, rectal temperature. Oxygen uptake and $\% \dot{V}O_{2\max}$ did not differ during the pre-load, confirming that the participants were working at the same relative exercise intensities. Heart rate ($F_{20,140} = 174.7$, $P < 0.001$) and rectal temperature ($F_{20,140} = 10.8$, $P < 0.001$) increased throughout the running period but did not differ between trials.

Indices: Glucose and cortisol concentrations. Glucose concentration increased throughout the trials but did not differ between collar conditions ($F_{5,30} = 7.9$, $P < 0.001$). Similarly, plasma cortisol concentrations increased following the time-trial but did not differ between trials ($F_{5,35} = 4.4$, $P < 0.01$). There was an increase in cortisol concentration at 10 min with the cold collar ($F_{10,70} = 2.3$, $P < 0.05$).

Affective states: Pleasure–displeasure (FS) and perceived activation (FAS) – “T90”. Throughout the running period, there was a significant difference in pleasure rating between trials ($F_{2,12} = 37.7$, $P = 0.02$) and ratings of pleasure changed with time, decreasing rapidly during the time-trial ($F_{7,42} = 23.8$, $P < 0.001$; Figure 1). The no-collar trial had the highest pleasure rating ($P = 0.02$). Similarly, perceived activation was highest in the no-collar trial ($F_{2,12} = 4.3$, $P = 0.04$; Figure 2).

Affective states: Pleasure–displeasure (FS) and perceived activation (FAS) – “steady state vs. time-trial”. Analysing the steady-state and time-trial segments separately showed that during the steady-state segment there was a significant difference in pleasure ratings between trials ($F_{2,12} = 6.7$, $P = 0.01$) but ratings of pleasure did not change significantly with time ($P = 0.07$; Figure 1). Tukey *post-hoc* tests revealed that no-collar participants reported significantly greater pleasure than participants in the uncooled collar ($P = 0.01$; $d = 0.9$) and cold collar ($P < 0.05$; $d = 0.2$) conditions. During the time-trial segment, incorporating the 75-min time point (to provide a practical baseline for the 15-min segment), there was no significant difference between trials ($P = 0.08$), but there was a significant change with time ($F_{3,18} = 11.7$, $P < 0.001$; Figure 1), indicating decreases in pleasure for all conditions across time.

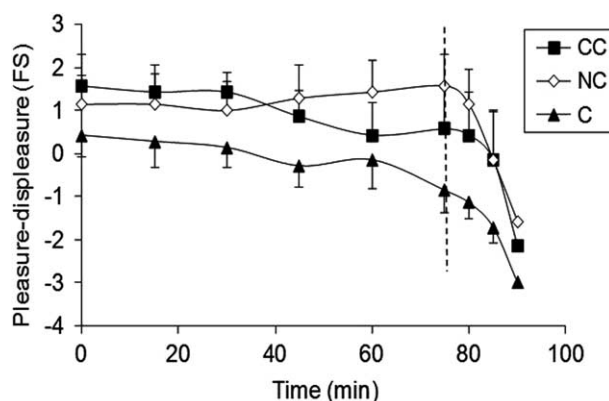


Figure 1. Mean ($\pm s$) pleasure–displeasure (Feeling Scale) during the 90-min pre-loaded time-trial. Main effect trial $P < 0.05$; main effect time $P < 0.001$. Vertical line represents end of pre-load (steady state, <75 min) and start of time-trial (≥ 75 min). CC = cold collar, NC = no collar, C = uncooled collar.

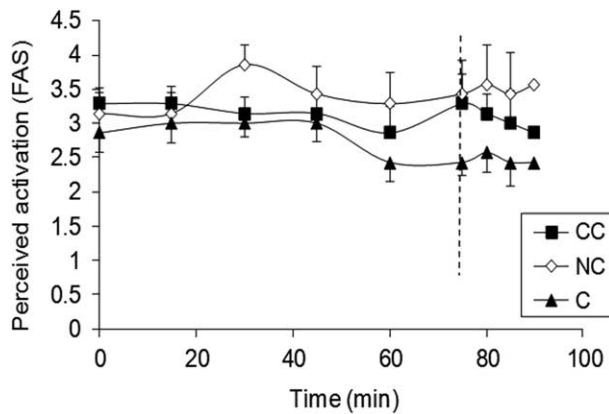


Figure 2. Mean ($\pm s$) perceived activation during the 90-min pre-loaded time-trial. Main effect trial $P < 0.05$. Vertical line represents end of pre-load (steady state, < 75 min) and start of time-trial (≥ 75 min). CC = cold collar, NC = no collar, C = uncooled collar.

For perceived activation, analysing the steady-state and time-trial segments separately indicated that during the steady-state segment there was a significant difference between trials ($F_{2,12} = 4.3$, $P = 0.04$) but ratings of perceived activation did not change significantly with time ($P = 0.08$; Figure 2). Tukey *post-hoc* tests revealed that there were significant differences for trial between the no-collar and collar conditions, with no-collar participants indicating higher perceived activation ($P = 0.04$; $d = 0.7$). During the time-trial segment, again incorporating the 75-min time point, there was a significant difference in perceived activation ratings between trials ($F_{2,12} = 4.3$, $P = 0.04$; Figure 2) with the no-collar participants reporting the highest ratings on the Felt Arousal Scale.

Rating of perceived exertion – “T90”. RPE was different between trials ($F_{2,12} = 3.8$, $P < 0.05$) and was lowest in the cold collar trial (Figure 3). RPE increased with time in all trials ($F_{19,133} = 87.8$, $P < 0.001$).

Rating of perceived exertion – “steady state vs. time-trial”. Analysing the steady-state and time-trial segments separately showed that during the steady-state segment there was no significant difference in RPE between trials ($P = 0.09$) but RPE did increase significantly with time ($F_{14,98} = 20.8$, $P = 0.001$; Figure 3).

During the time-trial segment, and incorporating the 75-min time point (as above), there were significant differences both between trials ($F_{2,14} = 3.9$, $P = 0.04$) and with time ($F_{5,35} = 64.1$, $P < 0.01$). *Post-hoc* tests revealed that uncooled collar participants reported significantly higher ratings of perceived exertion than their cold collar counterparts ($P = 0.04$; $d = 0.3$; Figure 3).

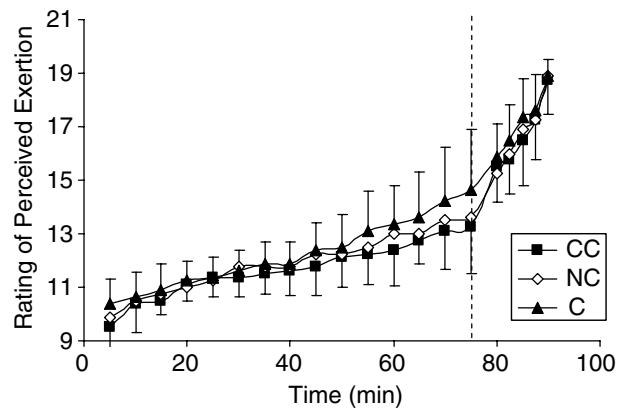


Figure 3. Mean ($\pm s$) rating of perceived exertion (RPE) during the 90-min pre-loaded time-trial. For clarity, standard deviation is not shown for no-collar trials; mean standard deviation for no-collar ± 1 . Main effect trial $P < 0.05$; main effect time $P < 0.001$. Vertical line represents end of pre-load (steady state, < 75 min) and start of time-trial (≥ 75 min). CC = cold collar, NC = no collar, C = uncooled collar.

Thermal sensation. Thermal sensation was significantly lower in the cold collar than uncooled collar condition ($F_{2,14} = 12.4$, $P < 0.001$; $d = 0.68$; Figure 4). Thermal sensation was also lower in the cold collar than no-collar condition ($P = 0.014$; $d = 0.46$). Thermal sensation was lowest in the cold collar trial and highest in the collar trial. Thermal sensation increased throughout the 90 min in all trials ($F_{20,140} = 44.5$, $P < 0.001$).

Discussion

The findings of the present study highlight that although performance was greatest for participants wearing the cold collar, affective indices showed that participants felt more pleasurable (Feeling Scale) and activated (Felt Arousal Scale) with no collar and, following that, indicated higher ratings for wearing a

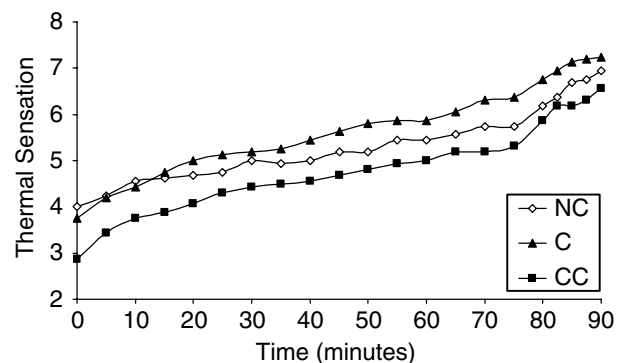


Figure 4. Mean ($\pm s$) thermal sensation during the 90-min pre-loaded time-trial. Main effect trial $P < 0.001$; main effect time $P < 0.001$. CC = cold collar, NC = no collar, C = uncooled collar.

cold collar compared with one that was not otherwise modified by temperature. In contrast, ratings of perceived exertion and of thermal sensation paralleled each other whereby highest ratings were provided by participants in the collar, then no-collar, and finally cold collar condition, respectively, providing further support for the notion that affect and perceived exertion are not isomorphic constructs (Backhouse et al., 2005, 2007a; Hardy & Rejeski, 1989). Put simply, the present findings support the notion that how one feels (affect) does not necessarily reflect what one feels (perceived exertion).

The current study incorporated psychological and perceptual indices, as well as physiological responses and indices, thus the following discussion is divided into these two sections to ensure that sufficient treatment is given to the key factors that have been identified as being relevant to this body of research, and that are consistent with previous psychophysiological research assessing similar parameters for endurance exercise (Acevedo et al., 2007; Backhouse et al., 2007a; Rudolph & McAuley, 1998).

Psychological and perceptual indices

The results revealed that participants experienced a rapid drop in pleasure–displeasure ratings during the time-trial across all conditions when FS ratings comprised both steady-state and time-trial data points (0 to 90 min inclusive). When the steady-state (pre-load) and time-trial segments were considered separately, there were no changes across time for the pre-load segment (<75 min) with the no-collar condition remaining the most pleasurable condition, whereas looking separately at the subsequent time-trial segment indicated that participants felt equally displeasurable across conditions in this latter 15 min. It is not surprising that a high increase in intensity during the 15-min time-trial would be perceived as substantially less pleasurable than the prior steady-state condition, and thus visually or graphically (although not theoretically) represent a sort of catastrophe effect similar to that shown by Hardy (1990), whereby athletes who go beyond their optimal arousal point experience a large and dramatic decline in performance, or a “catastrophe” from which it is very difficult for them to recover (Hardy, 1990). Although for obvious reasons this “catastrophe” phenomenon does not transfer directly over when independently considering the pre-load and time-trial segments, the separate analyses nonetheless lend support to the overall findings. Specifically, the lack of a collar is still perceived as more pleasurable than wearing a cold or uncooled collar during the steady-state exercise segment, and the collar is not a significant factor at all during the time-trial when the general feeling of displeasure

from the all-out effort becomes a far more prominent feature. Taken as a whole, the findings from the current research indicate that changes in pleasure appear to be linked to changes in intensity.

This finding is in line with other research (Ekkekakis, Hall, & Petruzzello, 2004, 2005; Ekkekakis & Petruzzello, 1999) that indicated that there is an association between reduced pleasure or increased displeasure and higher exercise intensities. It is important to recognize differences in methods for the current study compared with others. Specifically, some researchers have used incremental tests until volitional exhaustion (e.g. Ekkekakis et al., 2005) and this variation in the design seems to impact differently on individuals’ perceived pleasure in the closing stages of the exercise session.

In addition, recent research has investigated the use of the ventilatory threshold as a marker of transition from pleasure to displeasure with respect to exercise intensity (Ekkekakis et al., 2004; Rose & Parfitt, 2007, 2008) and exercise duration (Woo, Kim, Kim, Petruzzello, & Hatfield, 2009). In this study, participants transitioned across this threshold during the time-trial. While previous researchers have found an association between exercising above the ventilatory threshold and increased displeasure or reduced pleasure, findings from this research provided similar support.

For the current study, ratings of boredom–excitement (perceived activation) did not change as markedly for the no-collar and collar conditions, and dropped only slightly for cold collar participants during the time-trial; and these results largely held when considering the steady-state and time-trial segments separately. Both FS and FAS ratings were generally constant for participants during the sustained effort in the pre-load; but, following that effort, the participants’ perceived activation ratings generally remained high, yet were contrasted with drops in ratings of displeasure during the time-trial. These findings emphasize the importance of clarifying that “how” one feels in terms of *pleasure* is distinct from how one feels with respect to arousal or *activation*, which is also supported by previous research (Hall, Ekkekakis, & Petruzzello, 2002).

It may be that if athletes know that they have to maintain a set speed for a set time (75-min pre-load) and that immediately subsequent to that they will be required to produce an all-out effort (time-trial), then that awareness may cause – or even enable – them to maintain consistent, high levels of activation. However, regardless of the awareness of the task, it may simply not be possible to control or manage how pleasurable the task is when undergoing the time-trial or all-out effort. Ekkekakis and Petruzzello (1999) conducted a thorough review of research related to acute aerobic exercise and affect,

and noted that the literature revealed a lack of support with regard to different exercise bout durations having a differential impact on pre- to post-affective changes if intensity was kept constant. However, to date there is no research to the authors' knowledge that has looked at how affect may be influenced by changes in intensity (e.g. from a pre-load to a time-trial).

Taken as a whole, the two key points here are that: (1) current findings suggest that changes in pleasure are more closely linked to changes in intensity than is the case for activation, and (2) the use of both FS and FAS measures is warranted in future research. A practical implication of this finding is that coaches can manage athletes during high-intensity sessions in an appropriate way. For example, coaches can work with sport psychologists to help athletes to manage the displeasure – being comfortable with the uncomfortable – rather than focus attention on “psyching up” athletes for the session, as pain management may be a greater challenge for athletes than arousal regulation. It is worth noting, however, that there was only a single change in intensity in the current study, rather than a series of successive changes (e.g. interval training).

When examining the data from 0 to 90 min inclusive, cold collar participants reported significantly lower ratings of perceived exertion than participants in the uncooled collar and no-collar groups despite there being no differences in heart rate. In particular, ratings of perceived exertion were lowest for individuals in the cold collar condition between 40 and 75 min compared to those in the other two groups. These findings support previous research (Backhouse et al., 2005) and, fundamentally, these findings logically follow given that the design of the RPE scale was based on the premise that its values would effectively allow individuals to interpret heart rate and perceived effort alongside each other (Borg, 1975). In contrast, when considering the steady-state and time-trial segments separately, while participants' RPE scores increased with time for both portions of the exercise bout, there was only an effect of the collar for the time-trial portion whereby participants wearing an uncooled collar reported higher perceived exertion than when they wore the cooled collar. Overall, these results provide further support for studies that utilize both RPE and the Feeling Scale to gain a comprehensive understanding of participants' subjective experiences (Backhouse et al., 2005) while also incorporating other measures of affect such as the Felt Arousal Scale to clarify even finer distinctions in “how” an individual feels during exercise (Hall et al., 2002).

Examination of the findings of the data from 0 to 90 min in parallel with the steady-state and time-trial portions, which were also considered separately,

enables the elucidation of subtle but important differences that occur over a prolonged exercise bout where intensity of exercise differs. Taken in combination, the pleasure–displeasure (Feeling Scale), boredom–excitement (Felt Arousal Scale), and RPE findings from 0 to 90 min inclusive do not differ markedly from the steady-state-only and time-trial-only results, as both steady-state-only and time-trial-only findings indicated that how people objectively perform when wearing a cold collar does not necessarily mean that they subjectively feel better. A key finding when looking at the two segments separately, however, is that the use of a cold collar does not seem any more pleasurable for steady-state running than for high-intensity running, but that if people choose to use a cold collar to counterbalance effects of heat on exercise performance – which is relevant for a large number of competitors and sports as noted previously – then their perceptions of effort may be more likely to be moderated for high-intensity than steady-state exercise.

A final area to address in terms of the perceptual findings for this study is related to thermal sensations, as it would appear that individuals in the cold collar condition who exercised in the heat performed better because they felt cooler. In fact, reviewing the findings as a whole suggests that even though individuals *perceived* that they were both less hot and exerted less energy while performing better with the cold collar, they still *felt* the most pleasurable and activated without a collar. Taken together with findings for the other perceptual indices, there is strong evidence to suggest that there is still more that is unknown than understood about why and how individuals may “do better” but not “feel better”. The following section of the Discussion addresses this question.

Physiological responses and indices

Glucose concentration did not differ between trials in the present study, whereas differences in affect were reported. During exercise in the heat, Nybo (2007) outlined that there is a decrease in the cerebral glucose to oxygen uptake ratio as well as an increase in ratings of perceived exertion compared with exercise in a moderate condition (Nybo, 2007). The importance of glucose availability for enhanced mood during prolonged exercise has been reported (Backhouse et al., 2005; Lieberman, Falco, & Slade, 2002). Carbohydrate ingestion during prolonged moderate-intensity cycling increased feelings of pleasure compared with a placebo; however, towards the end of exercise, glucose concentrations were similar in both trials while pleasure ratings were different, suggesting that glucose concentration may not be the only factor altering affect ratings

(Backhouse et al., 2005). It is unclear what role, if any, the collar may have played with respect to glucose in the current study, but it is clear that the link between carbohydrate ingestion, blood glucose concentration, and affect warrants further investigation (Backhouse et al., 2005).

Research into hypoglycaemia and affect is equivocal with decreases in energetic arousal, increases in tense arousal, and negative mood states being observed (Gold, MacLeod, Frier, & Deary, 1995; Gonder-Frederick, Cox, Bobbitt, & Pennebaker, 1989). In addition, recent research (Backhouse et al., 2007a) has indicated that low plasma glucose concentrations ($<4.5 \text{ mmol} \cdot \text{L}^{-1}$) in the final third of a 90-min, high-intensity intermittent exercise correspond with lower perceived activation ratings, though no significant difference was reported for pleasure–displeasure. However, high glucose concentrations are also frequently related to negative moods, such as anger and sadness (Gonder-Frederick et al., 1989). The relationship between glucose response and affect, if any, is clearly a complex phenomenon that is worthy of further investigation. However, in the present study, it seems unlikely that glucose concentration had any effect upon the pleasure and activation ratings reported.

In the present study, there were no differences in cortisol concentrations between trials. Several studies have assessed the relationship between cortisol and affect with respect to exercise (Acevedo et al., 2007; Backhouse et al., 2005; Lai et al., 2005; Rudolph & McAuley, 1998). Similar to the findings of the present study, cortisol was shown not to be related to affect during prolonged moderate-intensity exercise by Backhouse et al. (2005). In contrast, Acevedo and colleagues (2007) reported that there was a similar pattern of cortisol response and increase in negative affect with increasing exercise intensity. However, it is unlikely that this is a causal relationship as cortisol concentrations increase with exercise intensity. Interestingly, some of the most current research has emphasized the need to consider and focus more on the findings with respect to cortisol and positive (versus negative) affect (Acevedo et al., 2007; Lai et al., 2005). Although research into affect and cortisol concentration is clearly limited to date, our research seems to agree with that of Backhouse et al. (2005) and Rudolph and McAuley (1998), that increases in cortisol concentration may not be strongly related to affect and that exercise intensity is more crucial in the cortisol response to exercise. In general, research is limited regarding the relationships between physiological responses, such as hormone, blood metabolite, and neurotransmitter concentrations and affect. Exercise in the heat and other environmental stressors are good models to study affect due to the strain that

individuals are placed under when exercising in these extreme environments.

Limitations, recommendations, and practical applications

Although the current study has built on previous research by assessing a range of psychological and perceptual affective indices alongside physiological parameters during prolonged exercise in the heat, it has some limitations. The main limitation was that, due to time restrictions, participants' affective ratings were not assessed following the session. This is an important factor for future research, as other researchers have noted post-exercise changes in affect with FS and FAS measures following moderate-intensity (e.g. Bellezza, Hall, Miller, & Bixby, 2009) and prolonged-intensity bouts (e.g. Backhouse et al., 2005). As previously noted, FS ratings of the participants in the current study markedly decreased and clearly diverged from the FAS ratings (which remained more constant) at the onset of the time-trial phase. While Backhouse et al. (2005) found two clear phases with respect to pre- and post-exercise pleasure–displeasure ratings within their study, it is quite possible that a similar picture would have been revealed in the current study and as such provided insight about distinctions pre- and post-exercise for both FS and FAS ratings. As reported previously (Backhouse et al., 2005, 2007a, 2007b; Ballezza et al., 2009), it is likely that athletes from this study would be highly likely to recover from their extreme drops in (psychological) pleasure ratings.

In addition, the participants in the present study were highly trained males, thus the findings may not be generalizable to other populations. Future research should include females, untrained individuals, and adolescents. Previous researchers have indeed noted variations in affective and physiological responses across a range of groups (cf. Ekkekakis & Petruzzello, 1999).

Given that exercise capacity (Galloway & Maughan, 1997) and performance (Tyler & Sunderland, 2008a) are both impaired in hot compared with moderate conditions, athletes are continuously searching for aids and means to reduce the negative cognitive and physical effects associated with training and competing in the heat. Recent research has indicated that pre-cooling can be useful for minimizing the adverse impact of heat on prolonged performance (Duffield et al., 2010; Marino, 2002), which is important not only for athletes who train and/or compete in certain sports (e.g. endurance runners and cyclists) or in hot climates for important competitions (e.g. 2004 and 2008 Summer Olympics), but also for individuals who enjoy a

range of outdoor activities (e.g. trekking/long distance walking), as well as those who normally work under hot conditions (e.g. firemen, military) and/or reside and work outdoors in hot climates (e.g. farmers).

From a practical perspective, individuals may genuinely prefer the “freedom” of not wearing a collar, so simply having training equipment that individuals *can* employ to improve their performance may not be sufficient if they feel uncomfortable using or wearing a particular apparatus (e.g. cold water immersion or cooling jacket). On the other hand, it is quite reasonable to assert that athletes who are likely to undertake diligent preparation for competition would also be likely to incorporate research-tested, evidence-based equipment into their regime if it has been shown to improve performance. Also, individuals who work under duress as a result of hot conditions are also quite likely to use devices or aids that would help them optimally perform their job. Therefore, a key implication of the current study is that education is of utmost importance in conveying the usefulness of the cold collar for performance improvements under hot conditions, and that managing people’s expectations from a psychological perspective is paramount for ensuring optimal adherence with and benefits from the cold collar as described in the current research.

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