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Research report

Caffeine ingestion, affect and perceived exertion during prolonged cycling☆

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ABSTRACT

Caffeine's metabolic and performance effects have been widely reported. However, caffeine's effects on affective states during prolonged exercise are unknown. Therefore, this was examined in the present study. Following an overnight fast and in a randomised, double-blind, counterbalanced design, twelve endurance trained male cyclists performed 90 min of exercise at 70% $VO_{2\ max}$ 1 h after ingesting 6 mg kg^{-1}BM of caffeine (CAF) or placebo (PLA). Dimensions of affect and perceived exertion were assessed at regular intervals. During exercise, pleasure ratings were better maintained ($F_{(3,38)} = 4.99$, $P < 0.05$) in the CAF trial compared to the PLA trial with significantly higher ratings at 15, 30 and 75 min (all $P < 0.05$). Perceived exertion increased ($F_{(3,28)} = 19.86$, $P < 0.01$) throughout exercise and values, overall, were significantly lower ($F_{(1,11)} = 9.26$, $P < 0.05$) in the CAF trial compared to the PLA trial. Perceived arousal was elevated during exercise but did not differ between trials. Overall, the results suggest that a moderate dose of CAF ingested 1 h prior to exercise maintains a more positive subjective experience during prolonged cycling. This observation may partially explain caffeine's ergogenic effects.

Introduction

Caffeine is the most widely used behaviourally active drug in the world and a common substance in the diets of most athletes (Chester and Wojek, 2008). Its widespread use, legitimised by its removal from the World Anti-Doping Agency (WADA) prohibited list of substances, is accompanied by an extensive literature that documents its physiological and performance enhancing effects (Goldstein et al., 2010; Graham, 2001a). Despite the scientific consensus that caffeine is ergogenic its mechanism of action remains elusive (Davis et al., 2003). Whatever mechanistic factors are in operation, the notion that caffeine alters subjective ratings of perceived effort during constant load exercise has been reinforced by the findings of a meta-analysis (Doherty and Smith, 2005). It is also commonly purported that caffeine ingestion alters behavioural functions such as vigilance, arousal and mood in resting and work-based environments (Smit and Rogers, 2000; Smith, 2002). Moreover, a number of studies have examined the interaction of caffeine and exercise on cognitive performance and noted favourable effects (Hogervorst, Riedel, Kovacs, Brouns, & Jolles, 1999; Hogervorst et al., 2008). However, caffeine's influence on the dimensions of affect during exercise has not been investigated. Such studies may yield important insights since it is posited that a favourable affective profile is beneficial to exercise performance (Acevedo, Gill, Goldfarb & Boyer, 1996) and continued exercise adherence (Backhouse, Ekkekakis, Biddle, Foskett, & Williams, 2007a).

Multiple mechanisms have been proposed to explain caffeine's ergogenic effect but the one that commands the most support suggests that caffeine competes with adenosine at receptor sites (Goldstein et al., 2010) and elicits subsequent elevations in the plasma concentrations of the catecholamines epinephrine and norepinephrine (Graham, 2001a). Such stimulation is thought to lead to increased wakefulness and vigilance (Daly, 1993; Nehlig, Daval & Debry, 1992). Such effects may be beneficial in those sporting contexts where cognitive processing is a core component. Indeed, a recent study by Foskett, Ali and Gant (2009) found that moderate doses of caffeine prior to a simulated soccer skill test resulted in enhanced fine motor skills as reflected by improved passing accuracy and ball control. Furthermore, prior research has demonstrated caffeine's beneficial effects on military tasks which simulate real-life activities. Nehlig and Debry (1994) have attributed task performance benefits derived from caffeine simply to an increased alertness or improved mood. In support, research on resting participants found that low to moderate doses of caffeine induce positive subjective effects such as improvements in well-being and self-rated happiness (Zwyghuizen-Doorenbos, Roehrs, Lipschutz, Timms & Roth, 1990). However, an inverted-U relationship has been noted with higher doses of caffeine eliciting feelings of anxiety and jitteriness (Griffiths & Mumford, 1995; Rogers, Smith, Heatherley & Pleydell-Pearce, 2008).

Traditionally, dimensions of affect have not been assessed in nutritional manipulation studies. Instead, the focus has been on

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"what" a person feels, as measured by the Rating of Perceived Exertion (RPE) scale (Borg, 1982). Alternatively, those few studies that have adopted a more encompassing subjective assessment (e.g., Welsh, Davis, Burke & Williams, 2002) have focused on the assessment of distinct variables, namely the six mood states (i.e., tension, depression, anger, vigor, fatigue and confusion) tapped by the Profile of Mood States (POMS) (McNair, Lorr & Droppleman, 1981) and little difference has emerged across carbohydrate and placebo conditions. Given the infancy of this line of research, dimensional models which examine the effect of nutritional manipulations on affect from a more unrestricted and parsimonious dimensional perspective (i.e., assessing core affect), may lay a solid foundation from which to build greater understanding. This appears to be a suitable assessment approach because whether one feels good or bad (pleasure–displeasure) or perceives an aroused state during exercise is highly relevant to those with an interest in studying exercise-supplementation effects or exercise adherence.

Thus, the pleasure–displeasure and perceived arousal dimensions of the circumplex model were assessed by the Feeling Scale (FS: Hardy & Rejeski, 1989) and the Felt Arousal Scale (FAS: Svebak & Murgatroyd, 1985), respectively. According to the circumplex model, the global affective space can be defined by two orthogonal and bipolar dimensions, namely affective valence (pleasure–displeasure) and perceived arousal (low to high) (Russell, 1980). Applying the circumplex model to the study of nutritional manipulations is appropriate because of its broad scope (theoretically, providing equal coverage to pleasant and unpleasant states) (Backhouse et al., 2007a). Furthermore, its parsimony is advantageous as it only requires the assessment of two affective states and therefore it is possible to obtain repeated measures of on-task exercise related affect.

In recent carbohydrate (CHO) manipulation studies participants have been asked to rate both "what" and "how" (affect) they feel during exercise and differential effects have emerged (Backhouse, Ali, Biddle & Williams, 2007b; Backhouse, Bishop, Biddle & Williams, 2005). For example, CHO ingestion noticeably prevented the observed reduction in pleasure noted in the PLA trial but attenuations in RPE were limited. These findings are relevant, given the ability of caffeine to delay fatigue and enhance exercise performance; it appears to entail complex processes involving the interplay between the central and peripheral nervous systems. Therefore, the purpose of the present study was to assess the effects of ingesting caffeine, prior to a prolonged bout of cycling, on affective states and perceived exertion. We hypothesised that pre-exercise CAF ingestion would attenuate reductions in the dimensions of affect and, in line with prior research we postulated that differential effects will emerge between affective valence and perceived exertion. More specifically, we hypothesised that the exercise bout would bring about a linear response on the RPE scale and a curvilinear response would be elicited using the Feeling Scale (Hardy and Rejeski, 1989).

Methods

Participants

Twelve endurance-trained males (mean ± SEM; age 24 ± 1 yr; body mass 73.5 ± 2.6 kg; $VO_{2\ max}$, 4.7 ± 0.2 l min^{-1}) volunteered to participate in the study. All participants were fully informed of the nature of the exercise trials before providing written consent to participate in the study. Ethical approval was granted by Loughborough University Ethical Advisory Committee. Prior to testing, participants were informed that the purpose of the study was to examine the influence of caffeine on physiological responses to prolonged cycling. No mention was made of the potential for positive/negative psychological outcomes during or following the exercise task in an attempt to reduce any potential expectancy effects. Moreover, the double-blind nature of the protocol also attempted to mitigate any caffeine expectancy effects.

A caffeine consumption questionnaire showed that average daily caffeine intake was about 228 ± 81 mg day^{-1}, indicating that most participants were low to moderate caffeine consumers, ingesting the equivalent of one to three cups of coffee per day. For reference, a standard cup of coffee typically contains 80–100 mg of caffeine.

Measures of affect and perceived exertion

The Feeling Scale (FS: (Hardy and Rejeski, 1989) was used as a measure of the affective dimension of pleasure–displeasure. Commonly used for the assessment of affective responses during exercise, it is an 11-point single-item bipolar rating scale. The scale ranges from +5 (*I feel very good*) to −5 (*I feel very bad*). Anchors are provided at the 0 point ('neutral') and at all odd integers. Participants were asked to rate how they felt at that particular moment. The instructions were: "*It is quite common to experience changes in mood whilst participating in exercise. Some individuals find exercise pleasurable, whereas others find it to be unpleasurable. Additionally feelings may fluctuate across time. That is one might feel good and bad a number of times during exercise. Scientists have developed a scale to measure such responses. Select the number that best represents your true feelings using the FS*"

The Felt Arousal Scale (FAS: (Svebak and Murgatroyd, 1985) is a 6-point, single item measure of perceived arousal. The scale ranges from 1 to 6, with anchors at 1 (*low arousal*) and 6 (*high arousal*). Again, participants were asked to rate how they felt at that particular moment. The instructions were: "*Estimate here how aroused you actually feel. Do this by pointing to the appropriate number. By "arousal" here is meant how "worked-up" you feel. You might experience high arousal in one of a variety of ways, for example as excitement or anxiety or anger. Low arousal might also be experienced by you in one of a number of different ways, for example as relaxation or boredom or calmness*".

Both the FS and FAS have been used in several previous exercise studies conducted by various laboratories around the world and have exhibited satisfactory convergent and discriminant validity (Backhouse et al., 2007a). The FS and FAS were administered prior to ingesting the test drink (pre-treatment), 1h post-ingestion (pre-exercise), every 15 min throughout the prolonged cycling bout, upon cessation of exercise and 5 min, 15 min, 30 and 60 min post-exercise. Participants were asked to rate how they felt at that particular moment. The Rating of Perceived Exertion scale was used as a measure of perceived exertion during exercise and was administered every 15 min during the trial. The scale ranges from 6 to 20, with anchors ranging from "very, very light" to "very, very hard". Again, participants were asked to rate their exertion at that particular moment. The instructions were: "*During the exercise bout, we want you to pay close attention to how hard you feel the exercise work rate is. This feeling should reflect your total amount of exertion and fatigue, combining all sensations and feelings of physical stress, effort, and fatigue. Don't concern yourself with any one factor, such as leg pain, shortness of breath or exercise intensity, but try to concentrate on your total, inner feeling of exertion. Try not to underestimate or overestimate your feeling of exertion; be as accurate as you can*". The RPE scale was presented first, followed by the FS and then the FAS.

Preliminary procedures

Maximal oxygen uptake ($\dot{V}O_{2\,max}$) was estimated by means of a continuous incremental exercise test on an electromagnetically braked cycle ergometer (Load Excalibur, Groningen, Netherlands) to volitional fatigue. Participants began cycling at 95 W, with