Research report
Caffeine ingestion, affect and perceived exertion during prolonged cycling

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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% VO2 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 (F3,28 = 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 (F3,28 = 19.86, P < 0.01) throughout exercise and values, overall, were significantly lower (F3,28 = 19.86, P < 0.01) 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 (Smith 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 Cant (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 Debruy (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 (Zwiryguizen-Dooenbos, 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, Heatherly & Pleydell-Pearce, 2008). Traditionally, dimensions of affect have not been assessed in nutritional manipulation studies. Instead, the focus has been on...
“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; VO₂ max, 4.7 ± 0.21 ml kg⁻¹ 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. More over, 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 “aroused” 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 (VCO₂max) 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 increments of 35 W every 3 min until volitional fatigue. Samples of expired gas were collected in Douglas bags during the 3rd minute of each work rate increment and heart rates were measured continuously using short-range telemetry (Polar Beat; Polar Electro, Oy, Finland). A paramagnetic oxygen analyser (Servomex 1420B; Crowborough, UK) and an infrared carbon dioxide analyser (Servomex 1415B) were used along with a dry gas meter (Harvard Apparatus, Edenbridge, UK) for determination of VE, V̇O₂ and V̇CO₂. The work rate equivalent to 70% V̇O₂max was interpolated from the V̇O₂–work rate relationship.

Participants then returned to the laboratory two days later in order to acquaint themselves with the exercise trials. During this familiarisation trial, participants cycled on an electrically braked cycle ergometer for 90 min at 70% V̇O₂max. Expired air samples were obtained and analysed as described above after the first 10 min and at 20-min intervals thereafter in order to ensure that the participants were exercising at the required intensity. If the participant was exercising at below 70% V̇O₂max or in excess of 75% V̇O₂max, the work rate was adjusted accordingly. Heart rates were monitored throughout this familiarisation trial.

Experimental procedures

To control for previous habitual caffeine use, all participants were instructed to abstain from caffeine containing products for at least 60 h preceding each trial. This period of time caters for washout, since half-lives reported for moderate doses of caffeine are between 2.5 and 4.5 h (Fredholm, Battig, Holmen, Nehlig & Zvartau, 1999). Participants were also instructed to refrain from alcohol intake and not to participate in any sporting activity during the 24-h preceding each main experimental trial. In an effort to standardise their nutritional status, participants were asked to consume the same foods and drinks during the 24-h prior to both experimental trials. Participants completed two exercise trials; each separated by at least 1 wk. They reported to the laboratory following an overnight fast of at least 10 h and were assigned to the caffeine (CAF) or placebo (PLA) trial in a randomised, double-blind, counterbalanced fashion. Participants responded to the FS and FAS (pre-treatment measure). Participants were then required to empty their bladder before body mass (in shorts only) was recorded.

During the CAF trial participants were given 6 mg kg⁻¹ body mass of caffeine (crushed Pro-Plus tablets, PP Products; Hertfordshire) dissolved in 3 ml kg⁻¹ body mass of artificially sweetened (aspartame) lemon flavoured water. This dose of caffeine was selected as most studies which have reported the positive effects of caffeine ingestion have given a dose of at least 5–6 mg kg⁻¹ an hour before exercise (Graham, 2001b). For a 70 kg person the chosen dose amounts to 420 mg of caffeine. This amount is commonly used in exercise research without any adverse side effects (Graham, 2001b). It has been clearly demonstrated that doses of at least 9 mg/kg or more are required to equal or exceed the former maximal acceptable caffeine concentrations of 12 mg/l of urine, set by the International Olympic Committee (IOC). Lastly, a single pre-exercise caffeine dose was selected because caffeine is rapidly absorbed by the intestine, and peak concentrations in blood appear at approximately 60 min after ingestion (Graham, 2001b). In the PLA trial, participants were given the same volume of the lemon flavoured water containing artificial sweetener without caffeine.

Participants then rested quietly in the laboratory for 1 h before responding once again to the FS and FAS. Participants then began cycling on the cycle ergometer at the work rate equivalent to 70% V̇O₂max for 90 min. Although the intensity was monitored, participants completed the exercise without continual adjustment of the resistive load on the cycle ergometer. In order to standardise fluid intake, participants consumed a further 2 ml kg⁻¹ body mass of water at 15 min intervals throughout the exercise on both trials. Participants responded to the FS, FAS and RPE at these times, prior to the consumption of water. Samples of expired air were collected into Douglas bags after 20 min of exercise and every 30-min thereafter for determination of V̇O₂ and V̇CO₂ and exercise intensity. Heart rates were recorded every 15 min during exercise using short-range telemetry (Sportester®, Polar Electro, Kempele, Finland). Laboratory conditions were recorded and an average temperature of 21.1 ± 0.3 °C and relative humidity of 52 ± 5% was noted.

Upon completion of the 90 min of cycling, participants immediately responded to the FS and FAS. Then body mass (in shorts only) was recorded. On both trials participants then consumed 5 ml kg⁻¹ body mass of water. Participants rested quietly and responded to the FS and FAS at 5 min, 15 min, 30 min and 60 min post-exercise.

Statistical analysis

A series of two-way analyses of variance (ANOVs) for repeated measures on two factors (experimental condition and sampling time) was used to examine the affective, physiological and perceived exertion data. Significant main effects were further analysed using paired t-tests and the Bonferroni adjustment for the number of pairwise comparisons was employed. Greenhouse-Geisser epsilon corrections were used when the sphericity assumption was violated. Statistical significance was set at the 0.05 level, apart from the Bonferroni analyses. Values are presented as means (SEM). No order effects were noted.

Results

Physiological responses to the exercise protocol

Exercise intensity did not differ between trials; mean ± V̇O₂max during exercise was 73.3 ± 0.6% in the CAF trial and 72.7 ± 0.6% in the PLA. Likewise, heart rates were similar between trials throughout exercise (CAF: 159 ± 3 beats min⁻¹, PLA: 159 ± 3 beats min⁻¹, mean of all recordings). Hence, caffeine ingestion did not differentially impact on exercise intensity or heart rate. Furthermore, participants were asked to indicate which treatment they thought they had received at the end of each trial but they were not able to differentiate between the treatments they received.

Affective states (FS and FAS)

Analysis on the FS revealed that during exercise pleasure rating was better maintained (condition × time interaction effect, F(3,38) = 4.99, P < 0.05, partial eta² = 0.33) in the CAF trial compared to the PLA trial where a marked decline was observed (Fig. 1). Specifically, pleasure ratings were significantly higher in the CAF trial compared to the PLA trial at 15 min (2.7 ± 0.3 vs 1.6 ± 0.3), 30 min (1.9 ± 0.6 vs 0.4 ± 0.6) and 75 min (1.5 ± 0.6 vs −0.5 ± 0.6; all P < 0.05). Upon cessation of exercise, a rebound effect was noted with pleasure–displeasure ratings returning back to baseline levels in both trials. Perceived arousal was elevated during exercise (F(4,26) = 11.83, P < 0.01, partial eta² = 0.52), but did not differ between trials.

According to the circumplex model, affective space is defined by two orthogonal and bipolar dimensions; an affective valence dimension (pleasant-unpleasant) and an arousal (high–low) dimension. Therefore, the FS and FAS were plotted in circumplex space (Fig. 2). The vertical axis of the circle marks the arousal dimension and the horizontal axis, the valence dimension. Affective states are construed as combinations of varying degrees of these two dimensions in such a way that they can be...
conceptualised as located around the perimeter of a circle defined by the valence and arousal dimensions. An assumption of the circumplex structure is a very high or low value on one dimension (e.g. arousal) is accompanied with a moderate value on another dimension (e.g. valence). The circle can be divided into 4 quadrants, producing the following meaningful variants: (a) activated pleasant (energy, vigor), (b) activated unpleasant (distress, tension), (c) unactivated pleasant (calm, relaxed), (d) unactivated unpleasant (fatigue, boredom). Plotting the FS and FAS in this dimensional space demonstrates that during the last 30 min of exercise, participants in the PLA trial were located in the 'unpleasant activated quadrant' of the circumplex model (Fig. 2a). This contrasts the CAF trial where participants remained in the 'pleasant activated quadrant' (Fig. 2b).

Perceived exertion (RPE)

Perceived exertion increased (main effect of time, $F_{(3,28)} = 19.86$, $P < 0.01$, partial eta$^2 = 0.64$) throughout exercise and values, overall, were lower (main effect of condition, $F_{(1,11)} = 9.26$, $P < 0.05$, partial eta$^2 = 0.46$) in the CAF trial compared to the PLA trial (Fig. 3).

Discussion

To our knowledge, this is the first study to determine the effects of caffeine ingestion on dimensions of affect and perceptions of exertion during exercise. Our results show that moderate doses of caffeine consumed 1 h prior to prolonged exercise induced reliable...
and reproducible changes in the pleasantness dimension of affect, as measured by the Feeling Scale (Hardy and Rejeski, 1989). More specifically, feelings of pleasure declined in the PLA trial but were better maintained in the CAF trial. As pleasure-displeasure and perceived arousal are interrelated within a circumplex model (Russell, 1980), the present study demonstrated that distinctive differences emerged across the two trials. During the latter stages of exercise, participants in the CAF trial remained in the activated pleasant quadrant of the circumplex (characteristic of energy and vigor), whereas in the PLA trial an unpleasant activated state was reported (characteristic of distress) (Fig. 2a and b). The divergent affective profiles induced were not explainable by differences in exercise intensity between the conditions because the two periods of cycling were performed at equivalent exercise intensities and with similar heart rates. Therefore, the results show that caffeine may be a useful supplementation practice for manipulating feelings of pleasure, albeit, during prolonged cycling in a laboratory.

The findings of this study have practical relevance for athletes because they commonly ingest caffeine prior to an exercise session. This decision appears motivated by a belief in caffeine’s ergogenicity. However, the multiple effects of caffeine on the body make it difficult to determine its principal mechanism of action (Lorist and Tops, 2003). In the exercise domain, free fatty acid mobilisation leading to glycogen sparing has been a putative hypothesis but in recent times this mechanism has largely been discounted (Graham, 2001a). Physical performance and behaviour is not governed by physiology and metabolism alone – affect, perception and cognition also play a role. This assertion is supported by an emerging literature suggesting that caffeine has wide ranging psychological as well as physiological effects. Therefore, the present finding is important because it implies that caffeine might improve exercise performance through positive subjective effects which may serve to enhance task persistence and determination (Acevedo et al., 1996).

In the present study ratings of perceived exertion were found to be lower in the CAF trial compared to the PLA trial. This finding is supported by the meta-analysis conducted by Doherty and Smith (2005) who reported that compared to placebo trials, caffeine ingestion reduced RPE during exercise by 5.6%. In the present trial, a 6.5% reduction in RPE was noted in the CAF trial compared to the PLA trial. However, in their review Doherty and Smith (2005) concluded that the dampening of perceptual responses was found to account for approximately 29% of the variance in the improvement in exercise performance. Therefore, given perceived exertion only partly explains subsequent ergogenic effects of caffeine on performance (Doherty and Smith, 2005) then the current study extends the traditional approach by combining the administration of the RPE scale with that of the Feeling Scale and Felt Arousal scale. On its own, the RPE scale provides limited information (Hardy and Rejeski, 1989), but this current approach serves to help our understanding of the subjective exercise experience following nutritional supplementation.

This study demonstrated that one can separate the experience of arousal from the feeling of pleasantness in an experimental manipulation as this research did not find any effects of the dimension of arousal during exercise. Although the limited exercise-affect-supplementation research base makes direct comparisons impossible, this finding contrasts with resting studies and in the military-field studies which have noted that caffeine consumption increases alertness (Smith, 2002). Differences in the methodologies of assessing arousal are offered as one explanation of this contrary finding. Furthermore, an important finding was that this treatment did not over stimulate the CNS to the point that negative affective states ensue and which in the field could override the positive ergogenic responses.

Caffeine is one of the oldest stimulants known to mankind and it has been argued that its most pronounced effects are evident in delaying the onset of fatigue (Lorist and Tops, 2003). One way in which caffeine might contribute to the delay in the onset of fatigue during prolonged heavy exercise might be through ‘feel good effects’, Doherty and Smith (2005) speculated that caffeine ingestion induces a greater capacity to tolerate the discomfort associated with exercise-induced fatigue, in essence operating as a masking agent. Although poorly investigated, caffeine’s antinoceptive properties mean that caffeine is present in several analgesic preparations (Laska, Sunshine, Wandling & Meisner, 1982). For example, ratings of leg muscle pain have been found to be significantly reduced following CAF ingestion when participants cycled to fatigue (Motl, O’Connor, Tubandt, Puettz & Ely, 2006).

The present study was not designed to identify the biological bases for the positive subjective changes and given that the majority of research has studied the effects of neurochemicals and central nervous system receptor blocking effects on behaviour in non-humans (Lorist and Tops, 2003; Davis et al., 2003) and that the biological correlates of positive affective states are only beginning to be described (Steptoe, Wardle & Marmot, 2005) further discussion is beyond the scope of the present study.

The ergogenic effects of caffeine have been criticised as not representing real enhancements in performance, but an alleviation of deficits induced by caffeine abstinence (James, 1997). Such an assertion is based on the fact that participants are generally asked to refrain from caffeine ingestion prior to testing. Whilst this is an acknowledged issue in the field, Doherty and Smith (2005) considered this moderator variable in their meta-analysis and noted that period of participant withdrawal from caffeine did not appear to have any major influence on the effects of caffeine on perceptions of exertion. However, it is important to note that the participants abstained from caffeine containing foods and drinks prior to testing. Given the average caffeine consumption of the participants was over 200 mg/day, the observed effects of caffeine might therefore reflect the reversal by caffeine of the adverse effects of caffeine withdrawal (Smit and Rogers, 2000). In order to distinguish between this explanation and the possibility that pre-exercise caffeine ingestion has net beneficial effects on subjective states, different experimental designs are required.

Limitations of the present study are that performance data were not collected and this should be paramount in future study designs; indeed, this is part of a research programme currently being undertaken. Plasma caffeine levels were not explicitly measured. However, a study by Walker, Caudwell, Dixon and Bishop (2006) measured serum caffeine concentration in response to exertion only partly explains subsequent ergogenic effects of caffeine ingestion, affect and perceived exertion during prolonged cycling.

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to the same exercise protocol in a similar group of participants. Although the data are not directly linked to the results of the present study, the finding provides support for the success of caffeine supplementation in elevating levels of caffeine in this study. Lastly, caffeine abstinence prior to the study could not be verified and therefore had participants consumed caffeine in the lead up to the study it could have affected the outcome of both the placebo and the caffeine trials. However, the information sheet and participant briefing impressed upon the participants the importance of adhering to the study guidelines.

In conclusion, this is the first study to assess the effects of caffeine ingestion on the subjective affect dimensions of pleasure–displeasure and arousal during prolonged cycling exercise. These states are worthy of investigation because they may play a key role in determining task persistence and effort (Acevedo et al., 1996) and ultimately the outcome of competitive sport. The findings have demonstrated that this supplementation regime was associated with a maintenance effect in relation to feelings of pleasure and lowered perceptions of effort. Moreover, the findings support previous assertions that researchers should assess a variety of subjective states, in addition to effort sense, in order to obtain a more accurate reflection of the exercise experience that accompanies nutritional supplementation. The observation of positive subjective effects may partially explain the ergogenic effects of caffeine and therefore future research should consider the interaction of affect, effort sense, pain and performance.

Uncited references

Hole et al. (2002) and Spriet and Howlett (1999).

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References


