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THE EFFECT OF CAFFEINE INGESTION ON ANAEROBIC PERFORMANCE IN MODERATELY TRAINED ADULTS

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Abstract Although studies have reported a positive effect of caffeine on aerobic performance, results relating to its effect on anaerobic performance are equivocal. The aim of this study was to examine the impact of caffeine ingestion on anaerobic performance in a group of moderately trained adults. Following ethical approval, 8 males and 6 females (Mean age = 21.8, *s* = 3.5 years) performed the Wingate anaerobic test on 3 occasions in randomised order, once where no substance was ingested (Control), once where a 5mg kg^{-1} of caffeine was consumed and once where a placebo was consumed. Results indicated that peak power output and mean power output were significantly greater in both the caffeine and placebo conditions compared to control (Both P = 0.001). Peak blood lactate values were significantly higher in the caffeine condition compared to the control condition (P = 0.04) but not between caffeine and placebo conditions (P<0.05). Rating of Perceived Exertion was higher in the placebo condition compared to the caffeine condition (P = 0.04) and there was no difference in peak heart rate across trials (P<0.05). These results suggest that caffeine ingestion does not enhance anaerobic performance over consumption of a placebo substance.

Key words: Peak power, blood lactate, Wingate test, placebo effect

INTRODUCTION

There is a plethora of research that has documented the beneficial impact of caffeine consumption on endurance capacity, particularly prolonged and exhaustive exercise [7, 13]. There is also mounting evidence for enhanced performance during short-term intense exercise lasting 4-10min [11]. However, the evidence for caffeine as an ergogenic aid for short-term, high intensity exercise is mixed [21].

Some studies have reported caffeine to have a beneficial impact on short term-high intensity exercise performance [15], bench press repetitions to failure [1] and Wingate test performance [21], whereas others have reported no beneficial effect when compared to placebo [4, 5, 9]. For example, Green et al [15] reported that consumption of 6mg kg^{-1} caffeine or a placebo did not significantly influence ratings of perceived exertion, peak heart rate, or the number of repetitions to failure completed during bench press exercise. This led them to conclude that the ergogenic effects of caffeine on resistance exercise performance might be limited but future research was needed to assess the impact of caffeine on high intensity exercise. Likewise, Paton et al [19] reported no significant differences in 20 metre sprint (10 repeats) performance and Greer et al [14] reported no ergogenic effect of caffeine on Wingate test performance.

Conversely, Doherty et al [11] reported higher mean power and lower rating of perceived exertion (RPE) during 3 minutes' high intensity cycling with caffeine consumption compared to placebo, and Stuart et al [20] concluded that caffeine provided substantial benefits in simulated high-intensity team sport performance. These variations have been attributed to various factors including training status and habitual caffeine use.

More recently, Woolf et al [21] examined the effect of 5mg kg^{-1} body weight caffeine compared to placebo on leg press, chest press and Wingate test performance in 18 male athletes. They reported that caffeine consumption resulted in significantly greater peak power attained during the Wingate test and greater weight lifted during the chest press. However, no differences were found between conditions for RPE, peak heart rate, plasma lactate and serum cortisol concentrations. Woolf et al [21] suggested that given the conflicting findings of prior research, the efficacy of caffeine as an ergogenic aid during anaerobic exercise remains uncertain and additional research is required to examine the efficacy of caffeine on anaerobic exercise performance.

Several theoretical explanations for the ergogenic effect of caffeine during high-intensity exercise performance have been suggested including increased performance due to the attenuation of fatigue [17] and that caffeine may act via the central nervous system to influence perception of exertion during exercise [10, 21]. However, as some studies have reported no differences in RPE with caffeine consumption [21] and others have reported RPE differences [9], further research is needed on this topic. Furthermore, Beedie and Foad [2] have also recently noted that the comparison of caffeine to placebo, as is common in studies of this nature, may mask the potential effect of caffeine on performance due to placebo effects. They suggest that future studies should incorporate a baseline condition where no substance is ingested in order to identify both the biological and psychological effects of caffeine on performance [2].

As a result, further research is needed on the impact of caffeine on short-term, high-intensity performance such as the Wingate anaerobic test (WANT) that takes on board recommendations regarding experimental designs suggested by other authors [2]. Therefore, the aim of this study was to examine the impact of caffeine consumption on WANT performance in moderately trained athletes.

MATERIALS AND METHODS

SAMPLES

Following institutional ethics approval and informed consent, 8 males and 6 females (mean age ± S.D. = 21.8 ± 3.5 years) volunteered to participate. All participants were free of any musculoskeletal pain or disorders and competed in team games (rugby union, football, basketball) at university level. They were currently participating in > 12 hours week programmed physical activity including strength and endurance activities. All participants were asked to refrain from vigorous exercise and maintain normal dietary patterns in the 24h prior to testing and were asked not to consume caffeine after 6:00pm the night before testing to control the effects of caffeine already consumed [18]. In order to confirm this, participants completed 24 hour dietary and exercise recall before each trial. Participants were required to follow the same diet in the day preceding each trial and were provided with a list of foodstuffs containing caffeine (e.g., coffee, chocolate, energy drinks) so they could refrain from caffeine intake. Where diet and/or exercise status were not maintained, participants were asked to return to laboratory on another occasion to complete their testing condition.

DESIGN

This study employed a within-subjects, repeated measures design. Participants were informed they were participating in a study examining anaerobic exercise performance and that as part of the experiment, they would be asked to perform the Wingate anaerobic test (WANT). All participants had regular experience performing the WANT as part of regular athlete physiological monitoring.

TESTING PROCEDURE

Each participant attended the human performance laboratory on three occasions. All testing took place between 9.00am and 12.00pm and at the same time for each participant to avoid circadian variation. Conditions were randomised and consisted of a control condition, where no substance was ingested, a caffeine condition where 5mg kg^{-1} caffeine was consumed diluted into 250ml of artificially sweetened water, and a placebo condition where 250ml of artificially sweetened water drink was consumed. Solutions were consumed 60mins before each exercise trial as plasma caffeine concentration is maximal 1 hour after ingestion of caffeine [13]. Prior to any exercise testing, body height (m) and mass (kg) were assessed using a Seca stadiometre and weighing scales (Seca Instruments, Germany).

Before the exercise tests, the participants completed a 10-min warm up consisting of both dynamic and static stretches. The exercise test consisted of a 30 second WANT completed on a Monark Peak bike (Ergomedic 894E, Vansbro, Sweden). Participants cycled with no resistance until they reached their perceived maximum speed. At this time, the predetermined load (7.5% body mass) was dropped and the test continued at maximal effort for 30 seconds. The peak power output (PPO) and mean power output (MPO) were calculated during the WANT using Monark's anaerobic testing software (version 1.0). Peak power was defined as the highest power output achieved during any 5 second interval and average power was defined as the average power over the 30 second test.

During each test peak heart rate (PHR) was assessed using heart rate telemetry (Polar Electro Oy, Kempele, Finland) and on completion of each test rating of perceived exertion (RPE) was determined using the Borg 6-20 RPE scale [6]. Peak blood lactate was also determined 2 minutes after each test using a capillary blood sample from the earlobe (Lactate Pro, Arkray Inc, Japan).

STATISTICAL ANALYSIS

Any changes in PPO, MPO, PHR, RPE and blood lactate were analysed using one-way, repeated measures, analysis of variance (ANOVA). Post-hoc analyses using Bonferroni adjustments were performed where any significant interactions and main effects were found. Partial η^2 was also calculated as a measure of effect size. A P value of 0.05 was used to establish statistical significance and the Statistical Package for Social Sciences (SPSS, Inc, Chicago, Ill) Version 15.0 was used for all analyses.

RESULTS

Results indicated a significant main effect for PPO ($F_{2, 26}$ = 14.98, P = 0.001, Partial η^2 = 0.535) and MPO ($F_{2, 26}$ = 15.5, P = 0.001, Partial η^2 = 0.544). Bonferroni post-hoc multiple comparisons indicated that PPO was significantly greater in the caffeine condition (Mean Diff = 70.2, P = 0.003) and the placebo condition (Mean Diff = 42.2, P = 0.005) compared to the control condition. There was no difference in PPO between caffeine and placebo conditions (Mean Diff = 28.3, P = 0.06). This pattern was replicated for MPO. Bonferroni post-hoc multiple comparisons indicated that MPO was significantly greater in the caffeine condition (Mean Diff = 40.7, P = 0.001) and the placebo condition (Mean Diff = 30.7, P = 0.002) compared to the control condition. There was no significant difference in PPO between caffeine and placebo conditions (Mean Diff = 13.5, P = 0.08). Mean ± SD for PPO and MPO across conditions are presented in Figures 1 and 2 respectively.

Peak heart rate was not significantly different across conditions ($F_{2, 26}$ = 2.9, P = 0.08, Partial η^2 = 0.182). There was, however, a significant difference in RPE scores ($F_{2, 26}$ = 6.9, P = 0.04, Partial η^2 = 0.348) with RPE values being higher in the placebo condition compared to the caffeine condition (Mean Diff = -0.643, P = 0.07). RPE values were not different between control and caffeine conditions (P = 0.08) or between control and placebo conditions (P = 0.1). In addition, peak blood lactate values were significantly different across conditions ($F_{2, 26}$ = 3.6, P = 0.04, Partial η^2 = 0.213). Bonferroni post-hoc multiple comparisons revealed that lactate values were significantly higher during the caffeine condition compared to baseline (Mean Diff = -0.436, P = 0.39). There were no significant differences in peak blood lactate values between the control condition and the placebo condition (P = 0.17) or between the placebo condition and the caffeine condition (P = 0.08). Mean ± SD of peak blood lactate, peak heart rate and RPE across conditions are presented in Table 1.

Table 1. Mean ± SD of Peak Bla, RPE and PHR across conditions

	Condition					
	Control		Caffeine		Placebo	
	Mean	SD	Mean	SD	Mean	SD
Peak Bla (mmol)	11.5	0.7	12.0*	0.7	11.8*	0.8
RPE	18.5	0.8	18.0*	0.6	18.6	0.6
PHR (BPM)	178.8	6.2	180.6	4.3	180.5	4.8

(* = significantly different to control condition).

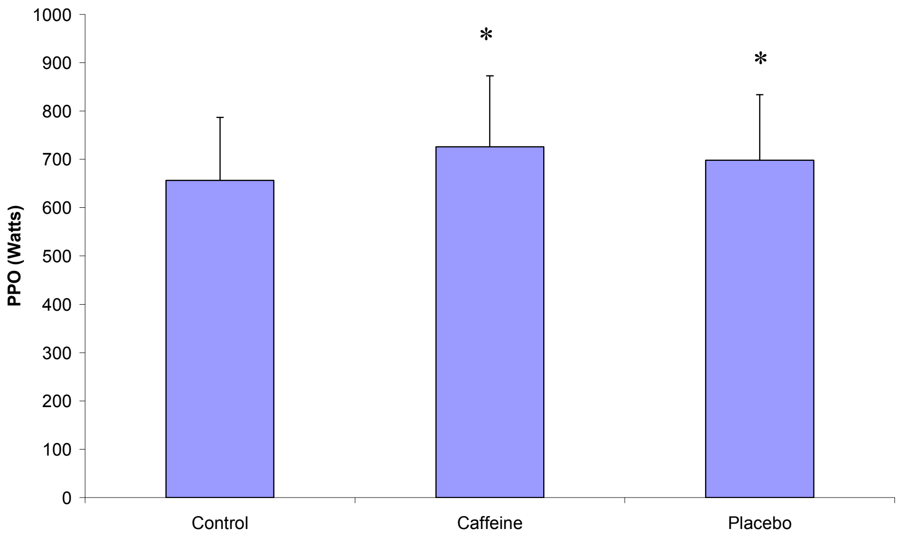

Figure 1. Mean ± S.D. of PPO (Watts) across conditions (* = significantly different to control condition)

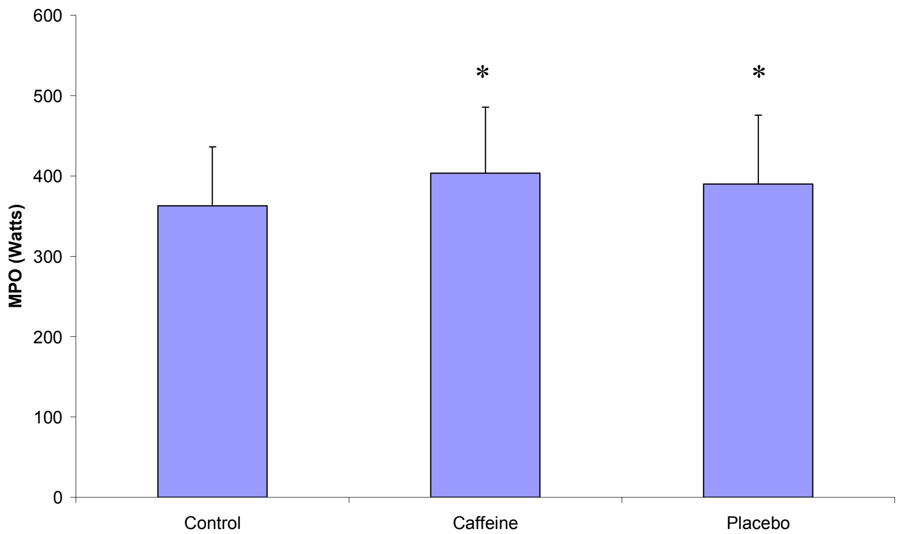

Figure 2. Mean ± S.D. of MPO (Watts) across conditions (* = significantly different to control condition)

DISCUSSION

The results of this study suggest that consumption of 5mg kg^{-1} caffeine significantly increases PPO and MPO during high-intensity anaerobic exercise above a control condition where no substance is consumed. This appears to concur with previous research that has also found significantly higher PPO during WANT test performance following caffeine consumption [21]. Similar to the work of Woolf et al. [21], the current study employed a participant group who were undertaking regular and structured exercise training for specific sports competition whereas participants in other studies have tended to be untrained or recreational participants only. The similarity in PHR across trials is congruent with other studies that have reported no significant differences in heart rates during maximal intensity exercise when caffeine or a placebo substance are consumed [21].

However, the fact that there were no significant differences in PPO, MPO and peak blood lactate values between caffeine and placebo conditions indicates that the placebo effect accounts for the improvements seen in the caffeine condition. It is important to note that in the present study, the experimental design employed sought to accommodate suggestions by previous researchers [3, 8] regarding the design of nutritional studies and sports performance. Traditionally, this has involved comparison of an active substance (in this case caffeine) with a placebo. Beedie and Foad [2] have noted that this design makes the assumption that the placebo is inert and does not influence performance. However, a number of studies have reported that the placebo effect can have a real and positive impact on sports performance [2, 3, 8]. As a result, Beedie and Foad [3] suggested that scientists interested in examining the impact of a proposed ergogenic on performance should employ a control condition where no substance was consumed as well as the active substance and placebo conditions. In this way, scientists can determine the true physiological effect of a given substance. In the context of the current study, PPO was significantly greater in both the caffeine and placebo conditions compared to the control condition. This would seem to suggest that placebo mechanisms account for some of the ergogenic effect of caffeine on performance. It may be as Beedie and Foad [2] note, that simply consuming a substance in the belief that it may have a performance enhancing effect will in turn result in performance enhancement. In this context the results of the current study agree with prior authors that have reported placebo effects of caffeine on aerobic based exercise [3] and short-term, high-intensity resistance exercise [12]. The study of the placebo effect in sports performance is still in its infancy and further research specific to the placebo effect of caffeine on various parameters of performance is needed to verify the suggestions made based on the results of this research.

In respect of RPE values, prior authors have suggested the caffeine dampens ratings of perceived exertion during exercise [11] and prior research on the impact of caffeine on WANT performance has reported no differences in RPE in caffeine and placebo conditions [21]. In the case of the present study, results indicated that RPE scores were lower in the caffeine condition compared to the placebo condition. These findings support prior research that has reported lower RPE following caffeine consumption [9, 11]. However, as noted earlier in the discussion, possible placebo effect mechanisms may also be in play here. It has been suggested that when an individual consumes a substance, they actively search for symptoms, and when these are not found this can result in negative placebo or ‘nocebo’ effects [2]. Although this is speculative, it may be that this is the case in the current study.

Furthermore, although the current study sought to control caffeine consumption and exercise status across trials, habitual caffeine intake was not strictly controlled across participants. As habitual caffeine intake may play a role in a person’s responsiveness to caffeine ingestion, it is possible that the results reported here were influenced by prior habitual caffeine consumption. Future research should account for this by ensuring that habitual caffeine users have an adequate washout period without caffeine ingestion before each experimental condition or by examining the impact of caffeine consumption on performance in habitual and non-habitual caffeine users.

CONCLUSIONS AND PRACTICAL APPLICATION

The results of this study suggest that, consumption of a caffeinated solution lowers the perception of exertion during high-intensity anaerobic exercise. However, there was no effect of caffeine over consumption of placebo, on peak power output, mean power output, peak heart rate and peak blood lactate values. This adds support to claims made regarding the placebo effect of caffeine on performance. Further research is needed to support these assertions with future authors considering a comparison of the effect of caffeine on anaerobic performance in trained and untrained populations and on habitual compared to non-habitual caffeine users.

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