Effect of Acute Creatine Supplementation and Subsequent Caffeine Ingestion on Ventilatory Anaerobic Threshold

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ABSTRACT

Quesada TD, Gillum T. Effect of Acute Creatine Supplementation and Subsequent Caffeine Ingestion on Ventilatory Anaerobic Threshold. JEPonline 2013;16(4):112-120. Ventilatory anaerobic threshold (VT) is an important indicator of cardiorespiratory fitness and metabolic adaptations. Creatine and caffeine are popular and effective ergogenic aides during aerobic and anaerobic exercise. The purpose of this study is to assess the effects of acute creatine supplementation and subsequent caffeine ingestion on VT. Seven moderately active males (age = 20.8 yrs ± 1.7, height = 178.9 cm ± 17.4, weight = 83.9 kg ± 17.4) completed the randomized, single blind, crossover design supplementation and interval running protocol. All subjects completed a placebo trial (PBO), creatine plus caffeine trial (CRE+CAFF), and caffeine plus placebo trial (CAFF). Two hours before the running protocol, subjects ingested 100 mg·kg⁻¹ of creatine or placebo, and 20 min before the protocol ingested 6 mg·kg⁻¹ of caffeine or placebo. The interval running protocol started at 6.0 miles·hr⁻¹ and increased 0.6 miles·hr⁻¹ every 3 min until volitional exhaustion. Ventilatory anaerobic threshold, maximal oxygen consumption (VO₂ max), heart rate (HR), rating of perceived exertion (RPE), and time to exhaustion (TTE) were measured. Ventilatory anaerobic threshold in CAFF (35.08 mL·kg⁻¹·min⁻¹ ± 5.7) was significantly higher (P<0.05) than PBO (29.05 mL·kg⁻¹·min⁻¹ ± 2.3). No difference between CRE+CAFF (32.68 mL·kg⁻¹·min⁻¹ ± 4.02) and PBO or CAFF and CRE+CAFF occurred. Maximal oxygen consumption, HR, RPE, and TTE were not significantly different (P>0.05) between groups. These results suggest that acute combination supplementation of creatine and caffeine does not improve VT, possibly due to their opposing metabolic mechanisms.

Key Words: VO₂ max, Ergogenic Aides, Metabolic Adaptations
INTRODUCTION

Physically active individuals and athletes often use multiple complementary ergogenic aids to enhance performance during aerobic and anaerobic exercise. Athletes, in particular, will supplement their training routine with creatine and/or caffeine to gain ergogenic effects such as increases in power, time to exhaustion (TTE), delay fatigue, and improved recovery (1,3,6,7,10,16,22,23). Combined supplementation of creatine and caffeine has been discouraged in the past (27,28), but more recent studies suggest that these supplements may be beneficially used simultaneously (6,16,23).

Creatine is stored in skeletal muscle as phosphocreatine (PCr), where it helps to rapidly resynthesize adenosine triphosphate (1,3,26). Creatine monohydrate supplementation facilitates phosphocreatine storage and has shown to be most effective in improving high-intensity, repeated bout, sprint performance with a short rest periods (3,10). Most studies that test the ergogenic effects of creatine use a 3 to 6 day loading regimen, which has exhibited increased skeletal muscle phosphocreatine storage, increased power, increased lean body mass, and positively affected ventilatory threshold (1,3,4,10). Schedel et al. (21) demonstrated that acute creatine supplementation enhanced secretion of human growth hormone, with the highest concentration measured between 2 to 6 hrs after ingestion. Cook and Crewther et al. (4) found that acute supplementation of creatine 90 min before a rugby passing skills protocol exhibited better accuracy and execution than the placebo or control groups.

Caffeine works as an A1 and A2a adenosine receptor antagonist, which is thought to be the main mechanism for caffeine’s ergogenic effects of fatigue resistance, lowered pain perception, and reduced RPE, while maintaining muscular excitability, especially during anaerobic activity (5,6,18,29). Furthermore, caffeine supplementation stimulates the central nervous system to produce effects such as increased TTE, mean power, mean speed, and agility at doses ranging from 3 to 7 mg·kg⁻¹ (7,6,22,25).

According to their respective mechanisms, creatine is an anabolic substance and caffeine is a catabolic substance. Earlier research concerning the combination of these supplements has suggested that caffeine inhibits the ergogenic effects of creatine during isokinetic muscle contractions, possibly due to the supplements’ opposite effects on muscle relaxation time (13,28). Vanakoski (29) found that the ergogenic effects of caffeine were not affected by creatine, but that creatine did not improve aerobic or anaerobic performance when taken with caffeine. Conversely, Doherty and Smith et al. (6) found that creatine absorption was not affected by acute caffeine ingestion 20 min before high intensity interval training (HIIT). Recent studies suggest that both creatine and caffeine may work together to produce effective aerobic and anaerobic enhancements when creatine loading occurs for approximately five days and caffeine is ingested in an acute manner 20 min to 1 hr prior to a running or cycling protocol (6,16,23). Previous studies have shown that consuming an energy supplement containing creatine and caffeine 10 min prior to a resistance training, endurance, or running protocol improved performance indicators such as VO₂ max, training volume, and power output (9,20,23).

Ventilatory anaerobic threshold (VT) is an important indicator of cardiorespiratory fitness and can aid in the prediction of onset of anaerobic/lactate threshold (8). Individuals that have similar maximal oxygen consumption (VO₂ max) may differ in regards to their VT depending on their level of training. Highly trained athletes will perform at a higher percentage of their VO₂ max with less lactate accumulation (8). Ventilatory anaerobic threshold occurs at the breakpoint when pulmonary ventilation (Vₑ) and oxygen consumption (VO₂) begin to rise in a non-linear trend. Also, aerobic
metabolism during exercise transitions to anaerobic metabolism at the VT. Creatine has
demonstrated the ability to improve VT by 16% during high intensity interval training (HIIT) (10).
Caffeine has not exhibited significant improvements in VT (14,19), but has demonstrated positive
effects regarding VO₂ peak (6).

Research has been clear that both creatine and caffeine are effective ergogenic aides to enhance
various aspects of aerobic and anaerobic performance (1,2,3,6,7,10,11,12,22,25,26). Research
regarding the effects of combination supplementation needs to be conducted so that active people
can become more confidently educated regarding the effects of the supplements they choose to
ingest for performance enhancement. More specifically, research is needed regarding the effects of
combining creatine and caffeine on VT. Thus, the purpose of this study is to assess the effect of
acute creatine supplementation and subsequent caffeine ingestion on VT. The hypothesis of this
study is that combination supplementation of creatine and caffeine will cause VT to occur at a higher
VO₂ when compared to placebo or caffeine alone.

METHODS

Subjects
Seven moderately active, college age, males participated in this study (age = 20.8 yrs ± 1.7, height =
178.9 cm ± 17.4, weight = 83.9 kg ± 17.4). Anthropometric data for height (cm) was measured using a
stadiometer (Tanita; Tokyo, Japan) and weight (kg) was measured on a Tanita scale (Tokyo, Japan).
Moderately active is defined in this study as performing moderate to intense exercise 3 to 5 d·wk⁻¹.
Potential participants were excluded if they had a musculoskeletal injury in the past year,
supplemented with creatine in the last 90 days (10), were caffeine naïve, or consumed in excess of
300 mg of caffeine per day (16). Subjects were recruited through social networking. Each subject
filled out a Physical Activity Readiness Questionnaire (PAR-Q). Subjects answered “no” in response
to all questions on the PAR-Q to be eligible to participate in the study. All participants signed a written
consent form explaining the supplementation and running protocol procedures. Subjects were asked
to maintain their normal physical activity and diet throughout the duration of the study (10).

Supplementation Procedures
This study utilized a randomized, single-blind, crossover, and placebo-controlled design. First,
subjects underwent a placebo trial (PBO) to provide familiarization to the running protocol and
supplementation methods. Two hours before their scheduled trial time, the subjects consumed 100
mg·kg⁻¹ of the creatine placebo substance, Stevia, mixed in 590 ml of Gatorade. The second drink
was ingested twenty minutes before the scheduled trial time, which consisted of one 1 oz packet of
the caffeine placebo Crystal Light mixed in 236 ml of water. Subjects were unaware that the PBO
trial occurred first because the method of supplementation did not change between trials. The
subjects were then randomly placed into either a creatine plus caffeine group (CRE+CAFF) or a
caffeine plus placebo group (CAFF) for the second trial and switched supplement groups for the third
trial. Trials were scheduled at least 72 hrs apart, with no more than 7 days between trials. Subjects
were asked to refrain from caffeine and alcohol consumption 24 hrs before each trial and to refrain
from exercise 24 hrs before each trial (4,6). Subjects reported to the kinesiology lab after a 3hr fast to
reduce the interference of food on supplementation protocol (16). All subjects ingested two beverages
before each trial. The first beverage was ingested two hours prior to the scheduled trial time, which
contained 100 mg·kg⁻¹ of creatine (Creatine Monohydrate 500, Metabolic Response Modifiers;
Oceanside, CA.), or placebo (Stevia), mixed by the researcher in 590 ml of Gatorade (4,21). The
second drink was ingested 20 min before the running protocol, which contained 6 mg·kg⁻¹ of caffeine,
or placebo, mixed in 236 ml of water and powered Crystal Light (6).
Running Protocol
The subjects completed three trials of the interval running protocol throughout the study. The running protocol consisted of 3-min intervals, which increased by 0.6 miles·hr⁻¹ from the previous stage, starting with 6 miles·hr⁻¹ and ending at volitional exhaustion (15).

Determination of VO₂ max, VT, HR, RPE, and TTE
Maximal oxygen consumption was measured through expired gases using indirect calorimetry on a Viasys metabolic cart (Yorba Linda, CA.). Ventilatory anaerobic threshold was determined through the V-slope method, in which VT is identified by the non-linear breakpoint between VO₂ and pulmonary ventilation (V̇E) (15). Heart rate was measured continuously by a Polar heart rate monitor strapped to the subjects’ chest (Kempele, Finland). Rating of perceived exertion was measured every 3 min by the researcher using Borg’s RPE scale.

Statistical Analyses
Power analysis suggested that a sample size of 7 subjects would produce a power of 0.84 (6,10). A repeated measures ANOVA was used to determine differences in VT, VO₂, and TTE. A 2-way (group x time) repeated measures analysis of variance (ANOVA) was performed using Statistica software (version 10) to examine differences between CRE+CAFF, CAFF, and PBO supplementation for RPE and HR. A Tukey Post-Hoc analysis was conducted if a significant P value of P<0.05 occurred. Data were screened for normality and homogeneity of variance before statistical analysis.

RESULTS
Subjects
Out of the 9 subjects that were recruited, 7 male participants completed this study. One subject was unable to finish all three trials due to caffeine intolerance and a second subject did not complete all three trials due to scheduling conflicts. Three of the 7 subjects that completed the study reported mild gastrointestinal discomfort only during the CRE+CAFF trial. The subjects demonstrated a significantly (P<0.05) higher VT during CAFF (35.08 mL·kg⁻¹·min⁻¹ ± 5.7) when compared to PBO (29.06 mL·kg⁻¹·min⁻¹ ± 2.3) as revealed by a Tukey Post Hoc analysis (Figure 1). There was no difference in VT between CRE+CAFF compared to CAFF or PBO. Subjects did not exhibit a significantly (P>0.05) higher VO₂ max between PBO (46.57 mL·kg⁻¹·min⁻¹ ± 4.14), CAFF (49.24 mL·kg⁻¹·min⁻¹ ± 6.2), and CRE+CAFF (47.15 mL·kg⁻¹·min⁻¹ ± 5.9) (Figure 1).

Figure 1. Ventilatory Anaerobic Threshold in Relation to VO₂ max Between Supplements.

VT and VO₂ max after consuming placebo, caffeine, or creatine and caffeine. *CAFF group exhibited a significantly higher VT than PBO, P<0.05. PBO vs. CAFF, P=0.04.
Rating of perceived exertion was not significantly (P=0.7) different between CRE+CAFF, CAFF, and PBO (Figure 2). Heart rate was not significantly different between CRE+CAFF, CAFF, and PBO throughout the running protocol, P=0.8 (refer to Table 1). Time to exhaustion was not statistically significant (P=0.88) between PBO (14:50 min ± 2:51), CAFF (15:51 min ± 4:26), and CRE+CAFF (15:07 min ± 3:24). Time to exhaustion was not statistically significant (P=0.88) between PBO (14:50 min ± 2:51), CAFF (15:51 min ± 4:26), and CRE+CAFF (15:07 min ± 3:24).

Figure 2. Rating of Perceived Exertion after Consuming Creatine and Caffeine, Caffeine Alone, and Placebo at the End of Each Stage during the Running Protocol.

Table 1. Heart Rate (beats·min⁻¹) at Different Time Points during the Running Protocol.

<table>
<thead>
<tr>
<th></th>
<th>3 min</th>
<th>6 min</th>
<th>9 min</th>
<th>12 min</th>
<th>15 min</th>
<th>18 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>PBO</td>
<td>141.4 ± 12.2</td>
<td>156.1 ± 13.2</td>
<td>166.8 ± 13.6</td>
<td>172.6 ± 13.5</td>
<td>177 ± 13.5</td>
<td>183 ± 14.7</td>
</tr>
<tr>
<td>CAFF</td>
<td>140.6 ± 15</td>
<td>158.1 ± 13.2</td>
<td>168.4 ± 21.1</td>
<td>176.3 ± 18.5</td>
<td>179.6 ± 21.5</td>
<td>178.7 ± 19.7</td>
</tr>
<tr>
<td>CRE+CAFF</td>
<td>145.4 ± 7.9</td>
<td>156.6 ± 12.2</td>
<td>167.3 ± 10.6</td>
<td>175.3 ± 11.2</td>
<td>180.2 ± 10.1</td>
<td>182.3 ± 11.8</td>
</tr>
</tbody>
</table>

DISCUSSION

Ventilatory threshold did not differ between the CRE+CAFF trial and PBO. However, VT was significantly higher in the CAFF trial, when compared to PBO. This may suggest that an interaction between the creatine (ingested 2 hrs prior to exercise) and caffeine supplements (ingested 20 min prior to exercise) occurs when taken in an acute manner, or simultaneously, as suggested by previous studies conducted by Hespel et al. (13) and Vandenberghe et al. (28). The anabolic mechanism of creatine and the catabolic mechanism of caffeine may have counteracted and caused a less than optimal utilization of each supplement during the running protocol. Also, Hespel et al. (13)
suggests that the opposing mechanisms may also account for each supplements’ opposite effects on muscle relaxation time.

Unlike some previous studies that used 3 to 6 days creatine loading regimens with subsequent caffeine ingestion 15 min to 20 min prior to exercise (6,16,23), this study used an acute supplementation approach for both creatine and caffeine. Acute supplementation of creatine and caffeine may have been the difference between the results of this study and others that found combination supplementation to be beneficial to athletic performance (6,16,23). According to Schedel et al. (19), acute creatine supplementation exhibited maximum human growth hormone blood serum concentrations between 2 hrs and 6 hrs after ingestion. This would suggest that the optimum performance outcomes should occur 2 to 6 hrs after creatine ingestion (21). Research by Gonzalez (9) and Ratamess (20) found that ingesting a beverage that consisted of creatine and caffeine 10 to 20 min prior to exercise increased power, training volume, and endurance. Vanakoski (27) found that the ergogenic effects of caffeine were not affected by creatine, but that creatine did not improve aerobic or anaerobic performance when taken with caffeine. Conversely, although not statistically significant, this study suggests that creatine may negatively affect the ergogenic properties of caffeine because both VT and VO₂ max were lower in the CRE+CAFF trial when compared to the CAFF trial.

Smith et al. (23) exhibited that ingesting a supplement containing creatine and caffeine 30 min prior to a high intensity running protocol improved VO₂ max. Although VT was significantly higher in the CAFF trial, VO₂ max was not significantly different between groups. This may indicate that VT is a more sensitive indicator of cardiorespiratory fitness than VO₂ max alone (8).

According to previous studies, caffeine should have produced a lower RPE than the placebo group (5,6,18,29). A reduced RPE is due to caffeine’s mechanism as an A₁ and A₂ adenosine receptor antagonist, which causes ergogenic effects such as lowered pain perception, while maintaining muscular excitability (5,6,7,18,29). Doherty and Smith (7) suggest that caffeine supplementation causes an altered perceptual response to exercise, which causes subjects to voluntarily exercise at a higher capacity with less effort and more motor unit recruitment.

Due to its properties as an adenosine receptor antagonist, caffeine has consistently exhibited the effect of raising HR throughout exercise (5,6,18,29). In regards to this study, 6 mg·kg⁻¹ of caffeine did not elicit a higher HR in the CAFF or CRE+CAFF groups when compared to PBO. Interestingly the CRE+CAFF group had a higher HR than CAFF, especially during the first 3 min of the running protocol and during the last 6 min, although the findings were not statistically significant. A well-documented side effect of creatine, possibly due to its anabolic properties, is water retention (6,21). Temporary water retention may have caused an increased HR. This may not be relevant in the current study because creatine was ingested in an acute manner 2 hrs before the running protocol; water retention due to creatine supplementation usually occurs when creatine is consistently loaded for 5 to 6 days (6).

Spradley et al (24) found that ingesting an energy supplement containing creatine and caffeine 20 min before a muscular endurance protocol improved lower body endurance and improved perceived energy. Lee et al. (17) suggests that combining creatine and caffeine actually improved TTE during a cycling protocol. The current study suggests that combining creatine and caffeine does not improve TTE. While the TTE in the CAFF trial lasted nearly 1min longer than PBO or CRE+CAFF, it was not enough to elicit statistical significance.
CONCLUSIONS

This study assessed the effects of acute combination supplementation of creatine and caffeine on VT. The findings from the current study suggest that acute creatine supplementation and subsequent caffeine ingestion had no significant effect on VT; however, the caffeine trial had a significantly higher VT than the placebo group. These findings can mainly be attributed to creatine and caffeine’s opposing mechanisms. This study suggests that moderately active males should avoid combining creatine and caffeine supplements for performance enhancement and that these supplements may be more effective when used individually.

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