The Effects of Low-Dose Caffeine on Perceived Pain During a Grip to Exhaustion Task

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ABSTRACT

Bellar, D, Kamimori, GH, and Glickman, EL. The effects of low-dose caffeine on perceived pain during a grip to exhaustion task. J Strength Cond Res 25(5): 1225–1228, 2011—This double-blind, placebo-controlled, within-subject experiment examined the effects of low-dose caffeine on pain reported during an exhaustive grip task. The grip task consisted of holding a metal block attached to standard Olympic weight plates with the arm at the side until the participants could no longer maintain their grip. Apparently healthy recreationally trained college-aged adults (men, n = 5; women, n = 5) were given either a piece of Stay AlertTM gum that delivered 85% of the effective dose of 100 mg of caffeine in 5 minutes or an identical placebo gum that contained no caffeine. Subsequently, pain perception and ratings of perceived exertion were recorded during an exhaustive grip task every 15 seconds and the overall time to exhaustion. No significant difference was found in time to exhaustion between treatments. A significant main effect of treatment for reported pain (p, 0.001, F = 0.377) was observed. Thus, in a population of recreationally trained college-aged adults, low-dose caffeine may attenuate the individual’s perception of pain during a grip to exhaustion task.

KEY WORDS analgesic, RPE, muscle pain, exhaustive exercise

INTRODUCTION

Caffeine is one of the most widely consumed psychoactive nutraceuticals. It has been reported that in the USA, caffeine consumption is on the order of 210–238 mg d−1 (21). Caffeine works as a sympathomimetic causing increased release of catecholamines and glucocorticoids in the central nervous system, which leads to physiological changes such as elevated heart rate and blood pressure (18,21). Three main actions of caffeine in vitro have been characterized: interaction with calcium ion channels in the sarcoplasmic reticulum, phosphodiesterase inhibition, and adenosine receptor antagonism (16,21). The first 2 explain why caffeine is 1 of the most widely studied substances with reported ergogenic properties.

Caffeine has been shown to increase running time to exhaustion (8,9) and cycling time to exhaustion (8,17). Further, caffeine has also been linked to increased time trial performance (4,6). The research to date on the ergogenic properties of caffeine in higher intensity shorter duration exercise has been equivocal (2,5,9,10,22) generating results that show both beneficial and nonsignificant effects. One possible explanation of the effects of caffeine on aerobic performance is a reduction in discomfort associated with the exercise. It was demonstrated that, after 2 hours of cycling with either caffeine or placebo supplementation, caffeine leads to increased plasma epinephrine, lactate, and cortisol levels as compared to placebo (17). In the same study, plasma beta-endorphins were also shown to be significantly elevated with the caffeine treatment. Early research on caffeine using animal models suggested that direct infusion of caffeine also leads to increases in plasma beta-endorphin levels but not in cerebral spinal fluid (1).

Beta-endorphins are endogenous opioid neurotransmitters that have analgesic properties (1). Therefore, if caffeine both enhances performance and leads to increase levels of beta-endorphins during exercise, it should make sense that pain associated with strenuous exercise should be attenuated with caffeine supplementation. Recent work by Motl et al. demonstrated that during 30 minutes of cycling, quadriceps muscle pain reported on an analog scale was reduced after 5 and 10-mg·kg−1 doses of caffeine as compared to placebo (20).

Based on a review of the literature, it can be hypothesized from the reported ergogenic and analgesic properties of caffeine that during an exhaustive upper-body task, performance may be enhanced and pain response attenuated with caffeine administration. The form of exercise chosen for the present investigation was selected because most people experience the need to grasp and hold objects during weight

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training exercise. The purpose of the present investigation was to examine the effect of a low dose of buccally administered caffeine (i.e., StayAlert chewing gum) on forearm muscle pain during an exhaustive grip task.

**METHODS**

**Experimental Approach to the Problem**

To evaluate the effects of low-dose caffeine administration on pain during an upper-body exhaustive exercise task a double-blind, placebo controlled, randomized repeated measures design was chosen. The design was such that it allowed for the comparison of the effects of caffeine in a controlled fashion accounting for placebo effects within the physiology of the same individual. The grip task to exhaustion was selected based on the need for people to grasp and hold objects repeatedly during weight training.

**Subjects**

The institutional review board at Kent State University approved the present investigation and all participants gave written informed consent and understood that they were free to withdraw from the study at anytime. The participants were 5 male and 5 female apparently healthy college students (Table 1). Participants were not categorized by habitual caffeine usage because recent work has demonstrated that both low and high habitual caffeine users responded to the analgesic effect of caffeine in a similar manner (7). Given the nature of the design, because subjects will be compared in a within-subject repeated-measures fashion, the caffeine usage of each will be statistically controlled for. Participants in the present investigation were recreationally trained, that is, did not participate in a training regime designed by a professional or as part of an intercollegiate athletic team.

**Materials**

**Grip to Exhaustion Task.** Participants completed 2 grip to exhaustion tasks, 1 for the placebo condition and the other for the caffeine condition. The task consisted of holding onto a 5-cm (wide) by 2-cm (deep) by 10-cm (long) metal block that was attached via a carabineer and strapped to standard Olympic weight plates (York Barbell, York, PA, USA). The participants grasped the block and held it with the arm extended by the side until they could no longer maintain their grip and dropped the weight. The weight was set to 30% of the value of grip strength test determined on the first visit via a Baseline® hand grip dynamometer (Medline Industries, Inc., Mundelein, IL, USA). The value of 30% was derived from pilot testing that was conducted a priori and evaluated to select a mass that would allow for a time course of approximately 1–4 minutes.

**Forearm Muscle Pain and Exertion Ratings.** Forearm muscle pain was measured using the 0–10 Numeric Pain Rating Scale (©Mosby Inc., Philadelphia, PA, USA). This scale as originally investigated by McCaffery and Pasero (19). The pain scale has 10 total ratings with verbal descriptors for the following: 0 = no pain, 5 = moderate pain, 10 = worst possible pain. Forearm ratings of perceived exertion were assessed via the standard Borg rating of perceived exertion (RPE) scale (4). This numeric scale has 15 total ratings beginning with 6 and ending with 20. Verbal descriptors accompany the following ratings: 6 = no exertion at all, 7 = extremely light, 9 = very light, 11 = light, 13 = somewhat hard, 15 = hard (heavy), 17 = very hard, 19 = extremely hard, 20 = maximal exertion. Both the Pain Rating Scale and the RPE scale were used to assess pain and exertion during the grip to exhaustion task every 15 seconds.

**Caffeine.** Stay Alert™ caffeine gum (KoKo Confectioners, Huntsville, MD, USA) was chosen as the method of caffeine administration for the present investigation based on the rapid nature of the delivery mechanism. The gum delivers 85% of the effective dose (100 mg) of caffeine after only 5 minutes of chewing (14). The rapid rate of delivery is due to the caffeine being absorbed via the buccal cavity, which is highly vascularized. The caffeine-containing gum and the placebo were of the same size, shape, color, and flavor.

**Procedures**

For the present investigation, apparently healthy, college-aged nonsmoking, nonobese participants were recruited. Participants were excluded if they had a history of smoking and obesity because this could interfere with caffeine metabolism (13,15). All participants completed 1 day of preliminary testing and 2 days of experimental testing. The experimental design was a double-blind within subjects. Participants were asked to abstain from ingesting caffeine for 12 hours before participating in the study. This period of abstinence was required to allow for clearance of caffeine.

**Initial Visit.** During the first visit, basic anthropometric data were collected including height and weight via a beam balance/stadiometer (Health-O-Meter, Bedford Heights, OH, USA). Three-site skinfold measurements were performed (Male: Chest, Triceps, Abdomen; Females: Triceps, Thigh, Suprailiac) using Lange Skinfold Calipers (Beta Technologies, Santa Cruz, CA, USA) by an experienced

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**TABLE 1. Participant characteristics (± SD).**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Male (n = 5)</th>
<th>Female (n = 5)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>23.0 ± 3.9</td>
<td>24.2 ± 1.5</td>
<td>0.541</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>172.3 ± 9.9</td>
<td>166.2 ± 9.8</td>
<td>0.359</td>
</tr>
<tr>
<td>Weight</td>
<td>86.2 ± 12.9</td>
<td>70.5 ± 9.4</td>
<td>0.058</td>
</tr>
<tr>
<td>Body fat %</td>
<td>14.5 ± 5.2</td>
<td>25.2 ± 3.7*</td>
<td>0.006</td>
</tr>
</tbody>
</table>

*p* values are the result of 1-way ANOVA analysis for variable by gender. *Significant difference from male gender.
exercise physiologist. Calculations of body density were preformed for the men according to the equations of Jackson and Pollock (11) and for the women using the equations of Jackson et al. (12). The Siri equation was used to convert body density calculations to percent body fat (23).

Participants were then given instructions for and practiced all portions of the time estimation task as previously described. Participants also performed the hand grip dynamometer test with their dominant hand. The peak pressure exerted in kilograms was recorded, and 30% of that force was selected as the weight for the grip to exhaustion task for each participant. Participants were also shown the 0–10 Numeric Pain Scale and the Borg RPE scale and became familiar with them. Finally, participants were given instructions about caffeine-containing foods and beverages and asked to abstain from caffeine ingestion 12 hours before their next 2 visits. These instructions included a list of common beverages and foods that contain caffeine.

**Experimental Visits.** During the experimental visits, participants reported during afternoon hours (1200–1800) and were given a piece of chewing gum (placebo or Stay AlertTM) to chew for 5 minutes. After the 5-minute period, participants were instructed to discard the gum. Immediately after the gum was discarded, the grip to exhaustion test was administered. Participants were instructed to hold their arm straight by their side and grip around the outside of the metal block with their dominant hand and resist dropping the weight for as long as possible. Every 15 seconds, participants were shown the 0–10 Numeric Pain Rating Scale and the Borg RPE scale and asked to respond.

**Statistical Analyses**
Before analysis, all dependent measures were examined for normality. Participant characteristics were analyzed via a series of 1-way analyses of variance (ANOVAs) to reveal differences between genders. Time to exhaustion by treatment was analyzed via a pair sample t-test. Forearm muscle pain and RPE were analyzed with a Mixed Model that included fixed effect (Treatment: Caffeine vs. Placebo), random effect (Pain or RPE) and repeated measures for Time (15 seconds–exhaustion). This form of analysis was necessary because each participant had a different time to exhaustion and thus a different number of reported scores for Pain and RPE during the exhaustive grip task. Time to exhaustion was analyzed via a repeated-measures ANOVA with Treatment (Caffeine vs. Placebo) and the repeated-measure Time (1,2). Significance was set a priori at alpha < 0.05. Sample size for the present investigation was selected based on a power analysis of previously reported findings of a similar design (20).

**RESULTS**
Intraclass correlation values were calculated for dependent measures and found to be >0.920. Participants’ (n = 10) descriptive statistics are listed as mean ± SD (Table 1). Intraclass correlations for all dependent measures were >0.80. Repeated-measures ANOVA analysis for time to exhaustion by treatment (Caffeine vs. Placebo) did not reveal a significant difference between treatments (Caffeine 104.98 ± 57.95 seconds, Placebo 99.85 ± 78.39 seconds, F(1,9) = 0.078, p = 0.786, ηp = 0.009), likely because of the large variance in performance by participants. Mixed-model analysis revealed a significant difference in reported values on the 10-point pain scale during the grip to exhaustion task (p < 0.001, Φ = 0.377) but not for the RPE scale (p = 0.411, Φ = 0.275). The mean response on the pain scale by treatment (Caffeine 3.45 ± 2.95 vs Placebo 4.84 ± 2.92) is given in Figure 1. The mean response on the RPE scale was very similar between treatments (Caffeine 13.45 ± 3.23 vs Placebo 13.32 ± 4.15).

**DISCUSSION**
The purpose of this experiment was to determine the effects of low-dose buccal caffeine administration on both forearm muscle pain reported and time to exhaustion during an exhaustive grip task. Compared with the placebo condition, participants reported lower pain scale scores after buccal caffeine administration. These data have confirmed the hypothesis that the analgesic effects of caffeine would be...
present in an upper-body exhaustive exercise task. Although the study found an analgesic effect for caffeine, the results did not support an ergogenic effect for the caffeine treatment. The overall time to exhaustion was not different between the treatments. Although the caffeine treatment did produce a mean time to exhaustion that was longer, the results were variable, and the mean difference was only 5 seconds. Therefore, the task itself was not affected by the 2 treatments. Also, the present investigation did not find a difference in the RPE reported between treatments. This would suggest that the participants self-reported a similar level of exertion between trials. Given the similarity in performance and RPE, the difference in reported pain clearly stands apart as an analgesic effect. Motl et al. (20) reported similar results during cycling exercise (20), though the doses used during this protocol were on average much higher (5 mg and 10-mg·kg⁻¹ bodyweight) than the average dose for the present investigation (mean 1.3 mg·kg⁻¹ bodyweight). The buccal technique of administration, which causes a quick rise to pharmacokinetic peak concentration in the blood, may be in part responsible for the similar results between the aforementioned study (20), and the present investigation even with the lower per kilogram dose used in the present investigation.

The results of the present investigation have expanded the understanding of altered pain perception with caffeine administration. Although other studies have investigated the effects of caffeine on pain during exercise (20), the present investigation is the first to report on an upper-body isometric exhaustive task. The isometric form of exhaustive exercise chosen is 1 that most people would have experience with, grasping and holding a heavy object. These data suggest that caffeine may provide an analgesic effect for these types of activities.

**Practical Applications**

Many activities that are involved in strength and conditioning require that an object such as an Olympic bar, kettle bell, or other equipment be held for a number of repetitions. The findings of this study suggest that small amounts of caffeine can reduce the discomfort associated with holding onto an object as the small muscles in the forearm become fatigued.

**References**