Original Research

Caffeine and Sprint Performance in Habitual and Caffeine Naïve Participants

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ABSTRACT

Int J Exerc Sci 5(1) : 50-59, 2012. Caffeine is thought to provide ergogenic benefits during endurance performance. However, there is limited research on the effects of caffeine on anaerobic sports performance. The purpose of this study was to examine the effects of 6 mg·kg-1 of caffeine on repeated sprint performance. The sample included active college students (N = 18), classified as habitual caffeine or caffeine naïve users. Participants completed a 12 x 30-m sprint test with 35 s rest intervals between sprints. Ratings of Perceived Exertion were collected every 3rd sprint. Height and body mass were measured and participants accommodated to the sprint test on Day 1. Participants were randomly assigned to the placebo or caffeine condition on Day 2 and the treatment was reversed on Day 3. Caffeine was ingested in a sports drink 1 h prior to performing the sprints. Caffeine produced a significantly faster best sprint time compared to the placebo trial, $F(1, 17) = 7.38$, MSE = .02, H-F p = .02. However, no significant difference was found between caffeine supplementation and placebo on time to complete the total sprint test. Additionally, no significant difference was found in sprint times with caffeine supplementation by sex or between caffeine-naïve and habitual caffeine users. Finally, a significantly higher average RPE was found with caffeine supplementation as compared to the placebo, $t(1, 17) = 2.92$, $d = .38$, $p = .01$. Caffeine has the potential to enhance sprint performance however, further research with women and habitual caffeine consumers is needed.

KEY WORDS: Ergogenic aids, repeated sprint ability, anaerobic exercise, methylxanthines

INTRODUCTION

Caffeine is one of the most frequently consumed drugs in the world, and has minimal health risks (18). It is found in numerous foods including chocolate and beverages, with coffee, tea, and soft drinks being consumed most frequently (16). Caffeine is also found in some over-the-counter medications and energy drinks.

Caffeine is quickly absorbed with plasma levels reaching a maximum level within 1 h of ingestion (18). Caffeine is slowly catabolized with a half-life or time to decrease its initial quantity by one half, of 4 to 6 h (18). Factors such as oral

contraceptive use and smoking may affect the half-life of caffeine (1, 7, 23). Caffeine is catabolized by the cytochrome P450 system in the liver to three dimethylxanthines: paraxanthine, theophylline, and theobromine, which are then further catabolized (18).

The details of how caffeine provides ergogenic aid to sports performance remain unclear, although several explanations have been proposed. Costill and colleagues proposed an increased use of fat as fuel for exercise thus sparing liver and muscle glycogen (13). An increased reliance on lipolysis benefits performance by conserving liver and muscle glycogen leading to delayed muscle fatigue. However, this mechanism may only be beneficial for endurance sports because the oxidative energy system is not dominant during anaerobic activities such as sprinting.

Another possible mechanism for caffeine's ergogenic effect during exercise is its effect on the central nervous system (CNS). Because of caffeine's lipid solubility, it is able to cross the blood-brain barrier (20) and act as an adenosine antagonist (14). The receptors that are most likely affected by caffeine are the A_1 and A_{2A} receptors (16). Caffeine's ability to act as an adenosine blockade in the CNS appears to be the most promising mechanism of action. While the mechanism of how caffeine may provide ergogenic aid remains debatable, much research has been conducted to test caffeine's effects during sports performance.

With the World Anti-Doping Agency (WADA) removing caffeine from the banned substance list in 2004 (26) and the National Collegiate Athletic Association (NCAA) setting a high urinary level of 15 μg/mL for a positive test (21), the door has now been opened for further investigation on the effects of caffeine on sports performance. Since 1978, numerous researchers have investigated caffeine's possible ergogenic effects on endurance capacity (4, 5, 6, 9, 13, 15). While many of the earlier studies provided mixed results, more recent studies clearly show that caffeine has the possibility to be ergogenic for both long-term and short-term endurance performance (4, 5, 6, 9, 13, 15), although the degree of its effects may depend on the characteristics of the users, such as level of training (12) and habitual use of caffeine (4).

Researchers have also investigated the effect of caffeine on anaerobic performance. Collomp et al. (11), Greer et al. (19), and Bell et al. (3) all failed to show improvement from caffeine in a Wingate testing protocol. While Wingate testing is purported to be a test of anaerobic power, it may be impractical for sports that involve multiple bouts of high intensity work. Repeated sprints are found in numerous sports including track, American football, basketball, and soccer. Because these sports have maximal or near maximal sprints accompanied by brief periods of rest or low intensity running, caffeine may be beneficial in these sports due to the mixed aerobic and anaerobic components.

Collomp et al. (12) found that specific training may be needed to see an effect from a 250 mg caffeine supplementation. These researchers concluded that intra- and/or extra-cellular adaptions that result

from specific training are necessary to benefit from caffeine during sprint performance. One potential issue with their study was the use of an absolute dosage of caffeine as opposed to a relative to body mass dosage. This may have provided smaller individuals with a greater effect and larger individuals with less of an effect from the caffeine.

Both Stuart et al. (25) and Schneiker et al. (24) found improved performance from tests designed to mimic the demands of various sports. Both studies used 6 mg·kg^{-1} of caffeine and found improvements in performance while caffeine levels remained below a positive drug test according to NCAA policy (24, 25). Glaister et al. (17) and Carr et al. (10) also found improved sprint performance from both 5 mg·kg^{-1} and 6 mg·kg^{-1} of caffeine. Participants in both studies were active individuals however, the studies included only male participants. While there are relatively few studies to investigate caffeine supplementation in a repeated sprint testing protocol, the lack of female participants is a recurring theme (10, 17, 22, 24, 25).

Paton et al. (22) however, found caffeine supplementation to not be beneficial in team sport athletes. This study did include a relative to body mass dosage, however the testing protocol may not have allowed enough rest time between sprints. The testing protocol consisted of 10 sprints each of 20 m in distance. Each sprint was required to be performed in 10 s with the remainder of that time for rest.

The ability to develop tolerance to caffeine effects is well known (16). There is an increase in the number of adenosine A_1 receptors following long-term caffeine use (16). Some researchers have attempted to address if differences exist in the effectiveness of a caffeine supplement on sports performance in those with habitual caffeine use compared to those consuming small amounts of caffeine. Dodd et al. (15) found no effect on VO_2 max or anaerobic threshold from a caffeine supplement of 5 mg·kg^{-1} in habitual and caffeine naïve participants. While resting metabolism and ventilation, as well as resting and exercise plasma free fatty acid (FFA) increased in the caffeine naïve group, this did not affect performance outcomes (15). However, Bell et al. (4) found that differences did exist between habitual and caffeine naïve users. Using a 5 mg·kg^{-1} body mass caffeine supplement and 6 exercise rides to exhaustion, the results indicated that the ergogenic effect was greater in nonusers, resulting in increased time to exhaustion. Controversy still exists if habitual use of caffeine will lead to decreased effectiveness of a caffeine supplement on sports performance.

Therefore, the purpose of this study was to examine the effects of ingesting 6 mg·kg^{-1} body mass of caffeine on performance in a multiple sprint running ability test with male and female participants who were either habitual caffeine consumers or caffeine naïve. It was hypothesized that caffeine ingestion would significantly decrease the time to complete the fastest individual sprint and total time to complete the repeated sprint protocol as compared to the fastest placebo trial and total time and that habitual caffeine users would see less improvement in fastest individual sprint times than caffeine naïve participants. Additionally, it was hypothesized that there would be no significant sex difference

in the effect of caffeine on sprint times (individual sprint times and total time to complete test procedure). Finally, it was hypothesized that average rating of perceived exertion (RPE) recorded during the repeated sprint testing protocol would be significantly lower in the caffeine trial as compared to the placebo trial.

METHODS

Participants

The participants included 18 active college students from the southeastern United States who were classified as caffeine naïve (6 males, 4 females) or habitual caffeine users (3 males, 5 females) based on a questionnaire created by the principal investigator. Most of the participants in the study were undergraduate exercise science majors. Three of the participants were NCAA Division I collegiate athletes playing basketball (n = 1) or softball (n = 2). Most participants had a history of sports participation in a variety of sports. None of the participants were smokers and all of the female participants but two were taking oral contraception. Demographic characteristics are presented in Table 1. Participants gave their verbal and written informed consent to participate in the study that was approved by the University Institutional Review Board.

Experimental design

Volunteers for the study first completed questionnaires, without knowledge of the study purpose, to assess their qualifications. The first questionnaire included questions on age, sex, Attention Deficit Disorder/Attention Deficit Hyperactivity Disorder (ADD/ADHD), contraceptive usage for female participants, exercise habits (including the types of exercise and for how long they participated in these activities), smoking habits, and lastly, caffeine usage. An attempt to include all forms of caffeine was made on this questionnaire which included soft drinks, as well as other drinks including, but not limited to, coffee, foods such as chocolate candy bars, over-the-counter medication, and prescription medications. Participants were asked to report use of the products on an "average" day's use.

Table 1. Demographics for the Sample (N = 18) and Female (n = 9) and Male (n = 9) Participants

	M	*SD*
Age (yr)		
Full Sample	21.2	1.5
Females	21.3	1.6
Males	21.1	1.5
Height (cm)		
Full Sample	174.3	8.3
Females	170.2	5.8
Males	178.4	8.6
Body Mass (kg)		
Full Sample	70.93	13.54
Females	64.14	10.91
Males	77.71	12.92
BMI (kg/m^2)		
Full Sample	23.3	4.1
Females	22.2	4.0
Males	24.4	4.1

Note. BMI = body mass index.

The second questionnaire was the Physical Activity Readiness Questionnaire (PAR-Q). To qualify for participation, participants had to be active (defined as engaging in at least 3.5 h per week of exercise), a non-smoker, caffeine naïve (defined as consuming less than 50 mg $\cdot$ day $^{-1}$ or less) or habitual caffeine user (defined as consuming equal to or greater than 300 mg $\cdot$ day $^{-1}$), not taking medication for ADD/ADHD, and finally have no health issues as determined by the PAR-Q. Terms to define habitual and caffeine naïve were similar to those previously defined by Bell et al. (4). Of the volunteers who met the

study requirements, 11 females (6 habitual caffeine users and 5 caffeine naïve) along with 11 males (5 habitual caffeine users and 6 caffeine naïve) were selected to complete this study.

During day 1, the participants' height and body mass were recorded. Body mass (to the nearest 0.1 kg) was measured via a scale (SECA; Hanover, MD) with the participants dressed in shorts and a shirt and the caffeine dosage was calculated from this measurement. Height was measured with a stadiometer (SECA; Hanover, MD) to the nearest 0.1 cm. Participants were asked to remove their shoes for both measurements. Using height and body mass, the BMI of each participant was calculated. Day 1 was also used to familiarize the participants with the testing protocol. After day 1, 4 participants (2 habitual caffeine males, 1 habitual caffeine female, and 1 caffeine naïve female) decided to withdraw from the study due to scheduling conflicts with coaches or injury.

Participants were given 3 days notice prior to days 2 and 3 and, consistent with previous literature (3, 6, 15), were asked to refrain from caffeine usage (all food, prescription medication, and beverages) and vigorous exercise 24 h prior to testing (3, 6, 15). This served as the washout period for previous caffeine usage to assure equal dosing. Participants were allowed to maintain their normal diet but were asked to avoid consumption of food or beverage (with the exception of the test drink) within 1 h of testing. All testing occurred within a 2 week time period with day 1 occurring during week 1 and experimental days 2 and 3 occurring during week 2 with 48 h of rest between trials.

Using a within-subjects experimental design, participants received either caffeine (6 $mg \cdot kg^{-1}$ body mass; Sigma Aldrich) mixed in a sports drink or a placebo (plain sports drink) 1 h prior to testing. All dosages were above all the participants' normal caffeine consumption (caffeine naïve M = 27.66 mg, habitual caffeine M = 314.80 mg). The treatment (caffeine or placebo) was distributed with participants blind to the condition (prescribed caffeine M = 425.57 mg). Assignment to the treatment condition was conducted in a randomized and counterbalanced manner. The treatment was reversed during day 3 for each participant for the counterbalanced experimental design. During all testing sessions, RPE, Borg scale 6 – 20 (8), was collected from the participants' every third sprint. Participants were equally encouraged and motivated to give their best effort before and throughout each testing session. Timing of the sprints was recorded electronically using a twin-beam photocell timing gate system (Brower Timing System; Draper, UT).

Before testing began on days 2 and 3, participants completed a standard warm-up consisting of 1 lap of jogging (self-selected pace) around the University's indoor track, ad libitum stretching, and a 1 x 30 m sprint. Using a similar testing protocol to Glaister et al. (17), participants individually completed a repeated sprint test (12 x 30-m; repeated at 35 s intervals). Sprints were performed in opposite directions to maximize the 35 s recovery time between sprints. Participants were instructed to stand behind the starting line to prevent premature triggering of the timing gates and were given a verbal 5 s

countdown prior to each sprint. Each sprint began with the participants in an athletic stance with their non-dominant foot forward.

Statistical analysis

The Statistical Package for the Social Sciences for Windows (SPSS Inc., Chicago, IL, Version 17.0) was used for statistical analyses. A repeated-measure analysis of variance (RMANOVA) was utilized to test the differences in the fastest sprint times and total time to complete the sprint test between the caffeine and placebo trials. An independent t-test was utilized to test the difference between the sexes and between caffeine naïve and habitual caffeine use on sprint times and total time to complete the sprint test. A difference score was created by subtracting the caffeine trial from the placebo trial for both the total time and individual sprints. Finally, a paired t-test was used to analyze average RPE from the caffeine and placebo trials. Average RPE was calculated by averaging the RPE of sprints 3, 6, 9, and 12. Cohen's *d* was used to calculate effect sizes. The method of Cohen's *d* used was (M_1 – M_2/ pooled *SD*). Pooled *SD* was calculated with the formula [(SD_1 + SD_2)/2]. The statistical significance was set at an alpha level of .05 for all analyses.

RESULTS

There was a significant difference between caffeine supplementation and placebo on the fastest individual sprint time for the full sample $F_{1, 17}$ = 7.38, MSE = .02, P = .02. However, no significant difference between caffeine supplementation and placebo was found on the time to complete the total sprint test for the full sample $F_{1, 17}$ = 3.94, MSE = 1.47, P = .06. While all mean sprint times were faster with caffeine, only sprints 3 and 5 reached the level of significance (see Table 2). Further, no significant sex difference was found in total time to complete the sprint test as well as individual sprint times with caffeine supplementation as compared to without caffeine supplementation (see Table 3). No significant difference was found between caffeine naïve (M = .08 s, SD = .14 s, n = 10) and habitual caffeine users (M = .17 s, SD = .24 s, n = 8) in the difference score of the fastest individual sprint times, $t_{1, 16}$ = -1.01, d = -.46, P = .33. Finally, a significantly higher average RPE was found with caffeine supplementation as compared to the placebo trial $t_{1, 17}$ = 2.92, d = .38, P = .01 (See Table 2).

Table 2. Sprint Times (s) and RPE for the Full Sample (*N* = 18)

	Caffeine Supplement	Placebo	Cohen's *d*
Sprint 1	5.25 ± .85	5.30 ± .83	-.06
Sprint 2	5.30 ± .83	5.38 ± .78	-.10
Sprint 3	5.25 ± .76*	5.36 ± .75	-.15
Sprint 4	5.28 ± .74	5.36 ± .69	-.11
Sprint 5	5.26 ± .70*	5.39 ± .71	-.18
Sprint 6	5.27 ± .68	5.33 ± .68	-.09
Sprint 7	5.32 ± .69	5.42 ± .74	-.14
Sprint 8	5.33 ± .66	5.40 ± .67	-.11
Sprint 9	5.37 ± .64	5.40 ± .62	-.05
Sprint 10	5.35 ± .65	5.37 ± .66	-.03
Sprint 11	5.36 ± .67	5.37 ± .63	-.02
Sprint 12	5.19 ± .58	5.27 ± .65	-.13
Fastest Sprint	5.03 ± .64	5.15 ± .65	-.18
Total Time	63.54 ± 8.29	64.34 ± 8.28	-.10
RPE Sprint 3	10.6 ± 2.0	10.1 ± 1.8	.27
RPE Sprint 6	13.1 ± 1.5	12.6 ± 1.8	.27
RPE Sprint 9	15.1 ± 1.5*	14.4 ± 1.5	.48
RPE Sprint 12	16.7 ± 2.0	16.1 ± 2.0	.33
Average RPE	13.9 ± 1.5**	13.3 ± 1.6	.38

Note. Values presented as mean ± standard deviation; RPE = Rating of perceived exertion; * *P* < .05; ** *P* = .01

Table 3. Difference in Sprint Times (s) Caffeine Supplement vs. Placebo by Sex

	Males ($n = 9$)	Females ($n = 9$)	Cohen's d
Sprint 1	-.03 ± .36	.12 ± .37	-.41
Sprint 2	.06 ± .25	.12 ± .17	-.28
Sprint 3	.10 ± .19	.11 ± .16	-.06
Sprint 4	.08 ± .21	.08 ± .28	.00
Sprint 5	.11 ± .18	.14 ± .22	-.15
Sprint 6	.01 ± .11	.11 ± .29	-.46
Sprint 7	.02 ± .14	.16 ± .23	-.74
Sprint 8	.03 ± .14	.10 ± .24	-.36
Sprint 9	.03 ± .09	.01 ± .26	.10
Sprint 10	.01 ± .13	.05 ± .21	-.23
Sprint 11	.04 ± .23	-.02 ± .18	.29
Sprint 12	.00 ± .11	.16 ± .25	-.83
Fastest Sprint	.06 ± .13	.18 ± .22	-.66
Total Time	.45 ± 1.50	1.15 ± 1.92	-.41

Note. Values presented as mean ± standard deviation

DISCUSSION

The purpose of this study was to test the effect of 6-mg·kg $^{-1}$ body mass of caffeine on multiple sprint running performance in active male and female participants who were either habitual caffeine consumers or caffeine naïve. Glaister et al. (17) was the model for this study. However, this study included both male and female participants and also examined the effect of the supplement on habitual and caffeine naïve users.

Caffeine ingestion produced a significant improvement in the fastest individual sprint as compared to the non-caffeine sprint trial. Consequently, the hypothesis that caffeine ingestion would significantly decrease the time to complete the fastest individual sprint was supported. This finding supports the results of previous studies showing improved performance with caffeine supplementation (2, 3, 4, 5, 9, 10, 12, 13, 17, 24, 25) and contrasts with other studies showing no improvement (11, 15, 19, 22). However, while the mean times with caffeine were faster for all sprints, only sprints 3 and 5 reached statistical significance. The lack of statistical significance on all sprints may have been due to the small sample size. The mean sprint times and effect sizes all indicate a decrease with the caffeine supplement that may reach significance with a larger sample size. While only two sprints reached the level of significance, the practical results show that caffeine has the potential to improve sports performance with sports that include multiple sprints.

No significant difference was found in the fastest individual sprint times with caffeine ingestion between caffeine naïve and habitual caffeine consuming participants. Therefore, the hypothesis that habitual caffeine consumers would see less of a reduction in the fastest individual sprint times with caffeine ingestion compared to caffeine naïve participants was not supported. The reason for the hypothesis that habitual caffeine users would see less of a benefit from caffeine was the physiological adaptations that occur with regular caffeine usage. It has been suggested that those who consume caffeine on a long-term basis build-up additional adenosine receptors (18) and therefore it may take more caffeine for the same effect in this group. The results of this study indicate that habitual caffeine usage potentially has no detrimental effect on caffeine's ergogenic effect in a sprint test protocol.

Similar terms were used to define caffeine usage in the current study and the study by Bell et al. (4) that also included male and

female participants. However, the finding in this study contradicts the finding of Bell et al. (4) who indicated nonusers received a greater benefit from caffeine supplementation. The key difference between the studies was the testing protocols with the present study being anaerobic in nature and that of Bell et al. (4) being an aerobic protocol. However, Dodd et al. (15) also found no significant difference between male habitual caffeine users and caffeine naïve users. These authors (15) defined caffeine usage in a similar manner to the present study.

The change in performance in individual and total sprint times in response to caffeine was not different in males and females. Thus, the hypothesis that that there would be no significant sex difference in the effect of caffeine on sprint times (individual sprint times and total time to complete test procedure) was supported. While this study found no sex differences with the supplement, more research studies are needed comparing sexes.

The average RPE for every third sprint was found to be significantly higher with caffeine than without caffeine. Therefore, the hypothesis that average rating of perceived exertion (RPE) recorded during the repeated sprint testing protocol would be significantly lower in the caffeine trial as compared to the placebo was not supported. This is an interesting finding because it is the opposite of traditional thought and previous research that indicates that caffeine lowers RPE (13). Glaister et al. (17), using the same testing protocol as this study, found no significant difference in RPE. In the study by Glaister et al. (17), which included measures of heart rate, the mean increase in heart rate was 3.4 bpm. A review article by Freedholm et al. (16) also indicated that high caffeine intake produces tachycardia. Glaister et al. (17) also reported increased blood lactate concentrations both pre-and post-testing with caffeine. Other studies have also reported increases in blood lactate levels with caffeine supplementation (2, 3, 10, 11). Although heart rate and lactate measures were not taken in this present study, if caffeine produced these same effects, this may be a reason for the increased RPE. Glaister et al. (17) also mentioned that increases in RPE corresponded with increases (decrement) in sprint time and heart rate, which indicates the validity of the RPE scale for a sprint testing protocol.

It is also important to note that while RPE was statistically different between conditions, the difference may not be practically significant. Because RPE is reported as a whole number, both the average RPE with and without caffeine was 13. This shows that while it was statistically significant, it was not different in a practical sense.

The strengths of the current study are the inclusion of female participants and both habitual and caffeine naïve users. The inclusion of female participants is lacking in the current literature testing caffeine's ergogenic effects (10, 17, 22, 24, 25). Few studies have evaluated the effects of caffeine supplementation on habitual and caffeine naïve users, (4, 15) and this is the first to date to evaluate the effects of habitual caffeine usage on a caffeine supplement in a sprint testing protocol.

This study also has limitations. One limitation of this study is the small heterogeneous sample size that included both collegiate athletes and recreationally active participants. The study by Collomp et al. (12) indicates that specific training may be needed to see a benefit from caffeine and the mixed sample may have produced mixed results. This is unlikely however because only 3 of the 18 participants were collegiate athletes. Another limitation of this study was the absence of heart rate and blood lactate measurements. Based on previous findings it is likely that both blood lactate and heart rate increased with the caffeine supplement.

Because this area is a relatively new area of study, more research is needed before definitive conclusions may be drawn about caffeine's effect on sprint performance. More research is needed to test if habitual caffeine use decreases the effectiveness of the supplement before a definitive conclusion can be drawn. Research is also needed using RPE because the perception of effort is an important component to examine in light of potential increases in heart rate and blood lactate. Research including females is needed to determine if caffeine's ergogenic effects are different for women and to determine the appropriate dosage time for women, because it may be different from that of men. This dosage timing is especially important for women using oral contraception, which has been shown to result in a longer time to metabolize caffeine (1, 23). While there was no documented sex difference in the current study, all but two of the female participants were taking oral contraceptives making it difficult to detect any difference due to oral contraceptive use.

In conclusion, the results of this study indicate that caffeine supplementation using 6 $mg \cdot kg^{-1}$ body mass does improve sprint performance. Furthermore, the results indicate that habitual caffeine use did not cause decreased effectiveness of the caffeine supplement and the effect did not vary by sex. Overall, this study shows that caffeine does have the potential to improve sprint performance and may be beneficial to sports that incorporate sprinting.

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