THE EFFECT OF CAFFEINE INGESTION ON MOOD STATE AND BENCH PRESS PERFORMANCE TO FAILURE

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ABSTRACT

Duncan, MJ and Oxford, SW. The effect of caffeine ingestion on mood state and bench press performance to failure. *J Strength Cond Res* 25(X): 000–000, 2010–Research has suggested that caffeine enhances aerobic performance. The evidence for high-intensity, short-term exercise, particularly resistance exercise is mixed and has not fully examined the psychological changes that occur after this mode of exercise with caffeine ingestion. This study examined the effect of caffeine (5 mg·kg^{-1}) vs. placebo on bench press exercise to failure and the mood state response pre to postexercise. Thirteen moderately trained men (22.7 $\pm$ 6.0 years) completed 2 laboratory visits, after determination of 1 repetition maximum (1RM) on the bench press, where they performed bench press repetitions to failure at a load of 60% 1RM. Mood state was assessed 60 minutes pre and immediately post–substance ingestion. Borg's rating of perceived exertion (RPE) and peak blood lactate (PBla) were assessed after each test, and peak heart rate (PHR) was determined using heart rate telemetry. Participants completed significantly more repetitions to failure ($p = 0.031$) and lifted significantly greater weight ($p = 0.027$) in the caffeine condition compared to the placebo condition. The PHR ($p = 0.0001$) and PBla ($p = 0.002$) were higher after caffeine ingestion. The RPE was not different across conditions ($p = 0.082$). Mood state scores for vigor were greater ($p = 0.001$) and fatigue scores lower ($p = 0.04$) in the presence of caffeine. Fatigue scores were greater postexercise ($p = 0.001$) compared to scores pre exercise across conditions. Caffeine ingestion enhances performance in short-term, resistance exercise to failure and may favorably change the mood state response to exercise compared to a placebo.

KEY WORDS high-intensity exercise, resistance exercise, repetitions to failure

INTRODUCTION

A wide range of research has documented enhanced performance in aerobic endurance performance after caffeine ingestion (1,11,23). This has been coupled with reduced ratings of perceived exertion (RPE) during submaximal, aerobically based exercise (14,15).

More recently, authors have suggested that caffeine ingestion might enhance high-intensity performance (4,7,22,40). Despite this, the effect of caffeine ingestion on high-intensity exercise lasting <3 minutes is equivocal (35). For example, Astorino et al. (4) reported a nonsignificant, 11 and 12% increase in total weight lifted at 60% of 1RM to failure during the bench press and leg press after caffeine consumption (6 mg·kg^{-1}) compared to placebo. Similarly, Green et al. (24) reported that caffeine consumption resulted in a greater number of repetitions and higher peak heart rate (PHR) during leg press to failure at 10 repetition maximum (10RM). Other studies have also reported increases in total weight lifted during bench press performance (40), increased number of repetitions during set 1 of leg extension performance (27), and increases in peak torque during 3–5 repetitions of leg extension and flexion (28).

Conversely, other studies have reported that acute caffeine ingestion did not enhance short-term resistance exercise (7,29). Beck et al. (7) found that 2.5 mg·kg^{-1} caffeine did not enhance 1RM bench press performance in untrained men. This was supported by further research that reported no significant effect on 1 repetition-maximum bench press strength and running time to exhaustion in 31 untrained men (Beck 2). Likewise, Williams et al. (39) found that 300 mg of ephedra and caffeine did not positively enhance 1RM bench press, lat pull-down, and Wingate test performance. However, in this latter study, participants were given an absolute dose of caffeine or placebo (300 mg) rather than a dose relative to body mass, thus limiting the extent of the conclusions that can be made from their results. More recently, Goldstein et al. (22) reported that acute caffeine ingestion (6 mg·kg^{-1}) significantly increased 1RM in the bench press but not bench press repetitions to failure at 60% 1RM in 15 resistance trained women. They concluded that a moderate dose of caffeine may be sufficient to improve upper body strength in resistance trained women but that further research on this topic was needed, particularly in women, to substantiate their claims.

Research using the Wingate anaerobic test performance is equally divided. Woolf et al. (40) reported that caffeine consumption of 5 mg kg^{-1} body weight resulted in a significantly greater peak power but not mean power attained during the Wingate test and greater weight lifted during chest press performance in 18 male athletes. Although the latter was nonsignificant, 78% of participants improved lifting performance in the caffeine trial. Conversely, research by Greer et al. (26) reported that ingestion of caffeine (6 mg·kg^{-1}) did not significantly enhance performance during 4 repeated Wingate tests. Other authors have also reported that caffeine does not significantly enhance Wingate test performance (9,12,26). Consequently, further research is needed on this issue as the efficacy of caffeine as an ergogenic aid during anaerobically based exercise remains uncertain (40).

One suggestion for the equivocal nature in previous research has been control of dietary practices, hydration status, prior caffeine intake, and training status of participants (4,23). In regard to training status of participants used, some studies have used trained (4,40) and others untrained performers (7,8). As such, there is a need to standardize and control for these variables to fully establish the effect of caffeine on performance. Data as to the effect of training status on responses to acute caffeine ingestion are therefore unclear; few studies have examined the effect of caffeine on short-term, high-intensity performance in trained individuals and additional research is needed on this topic (40).

Clearly, further research is needed to determine the impact of caffeine ingestion on high-intensity exercise generally and resistance exercise performance specifically (3,20). Moreover, Astorino and Roberson (3) have suggested that future research should also assess the impact of caffeine ingestion on psychological variables after resistance exercise. The RPE data suggest that acute caffeine ingestion dampens rating of perceived exertion (RPE) during prolonged, aerobic-based, exercise (14,15). Data relating to resistance exercise are less clear with Astorino and Roberson (3) concluding that caffeine does not seem to alter RPE on completion of resistance exercise but, because of the paucity of data on this topic, further investigation of this topic is merited.

One hypothesis is that, compared with a placebo, caffeine may dampen the serious withdrawal effects such as lethargy, irritability, and headaches reported with abstention from caffeine as is commonly required in scientific studies. Recent data reported improved resistance exercise performance in heavy caffeine users compared to men with lower habitual caffeine intakes (38). Furthermore, in this study, only 28% of participants correctly identified the caffeine condition but tended to report that they felt 'less tired' and had 'more energy' in the caffeine trial (38). Conversely, Green et al. (24) reported no significant changes in mood state after caffeine or placebo ingestion after 3 sets of bench press and leg press performance. One other study has reported that feelings of fatigue and vigor were positively influenced (although nonsignificantly) pre and post Wingate test performance after

acute ingestion of 5 mg·kg^{-1} caffeine compared to ingestion of a placebo or in a control condition where no substance was ingested (16). The extant studies examining the impact of caffeine ingestion on mood state are therefore sparse and equivocal. Astorino and Roberson (3) have stated that there is a need for further research to assess mood state before and during bouts of high-intensity resistance exercise to explore the contention that caffeine ingestion influences the mood response to exercise.

Therefore, the efficacy of acute caffeine ingestion on short-term, high-intensity exercise, particularly resistance exercise is unclear, and prior authors have suggested multiple avenues that need to be studied further to fully elucidate the effect of caffeine on this mode of exercise. The aims of this study were to examine the effect of acute caffeine ingestion on the following: (a) resistance exercise to failure and (b) RPE and mood state pre to postexercise in a sample of moderately trained men.

METHODS

Experimental Approach to the Problem

This study employed a within-subjects, repeated-measures design. Subjects were informed they were participating in a study examining the effect of an ergogenic aid on resistance exercise performance and that as part of the experiment, they would be asked to perform a 1RM test on the bench press and 2 subsequent testing sessions where they would be required to perform bench press exercise to failure at an intensity of 60% 1RM after ingestion of a sports drink or a placebo but that they would not be informed in what order which drink was consumed. Likewise, the investigator administering the solutions was naive to which order they were taken in by subjects. Because acute caffeine ingestion has been purported to influence a range of physiological, psychological, and performance variables (3,20,23), the experimental design used was designed to examine the effect of the independent variable (Caffeine vs. Placebo ingestion) on the following dependent variables that prior authors have suggested are influenced by caffeine ingestion (4,5,7,38): Bench press repetitions to failure (muscular strength endurance), peak blood lactate (PBla), PHR, RPE, and mood state. All testing took place within the institution's human performance laboratory.

Subjects

After institutional ethics approval and informed consent, 13 men (mean age $\pm$ SD = 22.7 $\pm$ 6.0 years) volunteered to participate. A priori power calculations had indicated that 12 participants were needed for a large effect size (0.8), at an alpha level of 0.05 with 80% power. All participants had specific experience performing resistance exercise and were free from any musculoskeletal pain or disorders. All participants competed in team games (rugby union, football, basketball) at University (i.e., national) level and had been competing in their respective sports for a mean time of 10.4 $\pm$ 2.3 years. They were currently participating in

>10 h·wk^{-1} programed physical activity including strength and endurance activities in addition to competitive fixtures in their respective sports. The participants were all part of the institution's sports scholarships scheme and as such participated in a minimum of 4 h·wk^{-1} strength and conditioning activity focused on Olympic lifting and plyometric training. The remaining elements of the participant's training included skill/strategy-based training and skills based games. All participants were asked to refrain from vigorous exercise and maintain normal dietary patterns in the 48 hours before testing. They were provided with a list of dietary substances containing caffeine and were asked not to consume caffeine after 6:00 PM the night before testing to control for the effects of caffeine already consumed (31). This was verified via a participant food diary including habitual caffeine consumption questionnaire (32) completed for the 48-hour period before each testing session. Similar to prior research on this topic (40,41) and to ensure familiarity with the effects of caffeine and to control for individual differences in reactivity to caffeine from caffeine habituation, only moderate caffeine users (ingesting approximately 200 mg·d^{-1}, range 169–250 mg·d^{-1}) were included in the study and preparticipation criteria required that participants had not consumed any other dietary ergogenic aids (e.g., creatine, protein, colostrum) in the 3 months preceding the testing.

Procedure

Each participant attended the human performance laboratory on 3 occasions. All testing took place between 9.00 AM and 12.00 PM, and each condition took place at the same time for each participant to avoid circadian variation. The first visit to the laboratory involved a briefing session and determination of each participant's 1RM on the bench press. All participants had experience performing resistance exercises in general and bench press exercise in particular. However, before commencing the 1RM, the bench press was demonstrated to each participant. Each participant also performed 8–10 unweighted repetitions to minimize any learning effects that could occur in the experimental protocol. The 1RM was determined according to methods advocated by Kraemer et al. (30). Proper lifting technique was demonstrated for the participants before the 1RM assessment. The 1RM value was used to set the 60% 1RM intensity undertaken during the proceeding experimental trials.

During each condition, participants undertook a 5-minute submaximal warm-up on a cycle ergometer and then completed 1 set of bench press exercise to failure at 60% 1RM. Prior studies examining the impact of caffeine on resistance exercise performance have also employed this methodology (4,24). Conditions were presented in a randomized order and were separated by 24–72 hours. Conditions were randomized and consisted of a caffeine condition where 5 mg·kg^{-1} of caffeine diluted into 250 mL of artificially sweetened water and a placebo condition where 250 mL of artificially sweetened water drink was consumed. Solutions were consumed 60 minutes before each exercise trial because plasma caffeine concentration is maximal 1 hour after ingestion of caffeine (23). Each solution was presented to participants in an opaque sports bottle to prevent the researchers who administered the solutions or the participants consuming the solutions from actually seeing the solutions themselves. Before any exercise testing, body height (m) and mass (kg) were assessed using a Seca stadiometer and weighing scales (Seca Instruments, Hamburg, Germany).

Lifting Procedures

Bench press exercise was performed using a 20-kg Eleiko bar and Pullum Power Sports lifting cage (Pullum Power Sports, Luton, United Kingdom) and in accordance with protocols previously described for the bench press by Earle and Baechle (19). The starting position required the participant to lie supine on the bench with eyes below the racked bar and the participant grasping the bar with a closed, pronated grip slightly wider than shoulder width apart. With knees slightly flexed, feet on the floor and with assistance from the spotter the bar was moved off the supports to a position over the participant's chest. The bar was then lowered to touch the chest at approximately nipple level with wrists stiff and forearms perpendicular to the floor. The participant then pushed the bar upward until the elbows were fully extended without arching the back or raising the chest to meet the bar (19). A trained spotter was present during all testing sessions to ensure proper range of motion. Any lift that deviated from proper technique was not counted. During all conditions, repetition frequency was paced by a metronome set at 60 b·min^{-1}. This cadence resulted in 1 complete repetition every 4 seconds with concentric and eccentric phases comprising 2 seconds each. Subjects were given verbal encouragement throughout the protocol. Feedback related to lifting procedures or the number of repetitions completed was not made available to participants until completion of the whole experimental procedure.
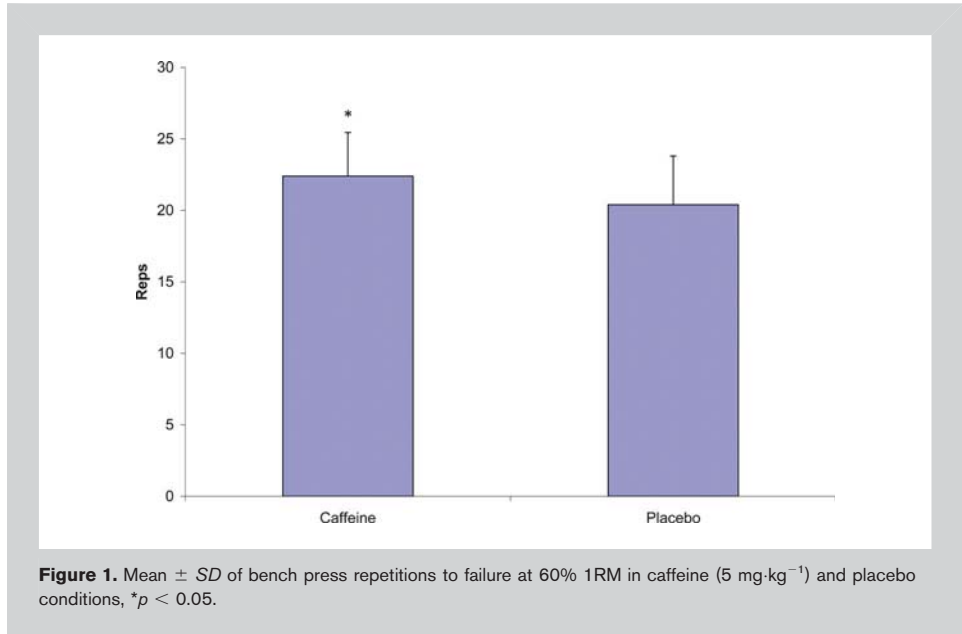
Performance Measures

During each condition, repetitions were counted using a hand tally counter (Tamaco Ltd, Tokyo, Japan) and PHR was assessed using heart rate telemetry (Polar Electro Oy, Kempele, Finland). Total weight lifted (kg) was calculated by multiplying the mass lifted by the number of repetitions completed. Immediately after participants had reached failure, they were asked to provide ratings of perceived exertion using the Borg CR10 RPE scale (10). ThePBla was also determined 3 minutes after each test using a capillary blood sample from the earlobe (Lactate Pro, Arkray Inc, Shiga, Japan) (6,11,25). In addition, mood state was assessed 60 minutes before beginning the exercise protocol (i.e., pre caffeine or placebo ingestion) and immediately post each experimental condition using the Brunel Mood State Inventory (BRUMS, 37). This measure of mood is a well-established, reliable and valid measure of mood state that has

been previously employed to assess the mood state response to various exercise modes (36,37).

Once the experimental protocol had been completed, but before participants were informed of the values assessed during each condition, participants were asked to indicate which trial they perceived to be the caffeine ingestion trial and were asked to provide explanations for their decisions. The participants were asked 'Please identify which trial was the trial where caffeine was consumed and which was the trial where the placebo was consumed'. After this, the participants were asked 'Please could you explain why you believe this to be the case' and then 'are there any other reasons why you think this was the case.' The researchers recorded the responses to these questions and they were used as a form of post hoc qualitative analysis. After completion of all conditions, participants were thoroughly debriefed.

Statistical Analyses

Because the aims of this study were to assess the effect of acute caffeine ingestion on resistance exercise to failure, and RPE and mood state pre to postexercise, any changes in total repetitions completed, total weight lifted and RPE and physiological indices assessed during the experimental conditions (PHR and PBla), across the caffeine and placebo conditions were analyzed using paired samples t-tests for each variable. As mood state was assessed before substance ingestion and immediately after the exercise task in both conditions, any changes in BRUMS subscales were assessed using a series of 2 (pre to post) $\times$ 2 (condition, caffeine vs. placebo) ways repeated measures analysis of variance (ANOVA). Post Hoc analysis 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. Intraclass correlation coefficients (R) were 0.823 for repetitions and 0.953

Figure 1. Mean $\pm$ *SD* of bench press repetitions to failure at 60% 1RM in caffeine (5 mg·kg^{-1}) and placebo conditions, *$p < 0.05$.

for total weight lifted indicating good reliability across experimental conditions. A p value of 0.05 was used to establish statistical significance and the Statistical Package for Social Sciences (SPSS, Inc, Chicago, IL, USA) Version 15.0 was used for all analyses.

RESULTS

Results indicated that participants completed significantly more repetitions to failure (t[12] = 2.449, p = 0.031, Partial η^2 = 0.361, Figure 1) and lifted significantly greater weight (t[12] = 2.514, p = 0.027, Partial η^2 = 0.323) in the caffeine
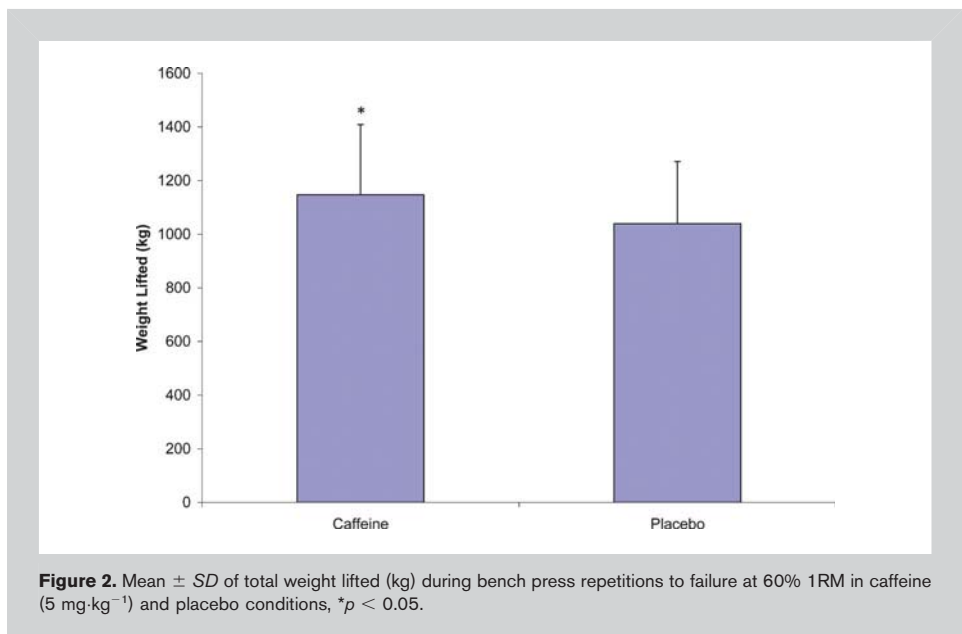

Figure 2. Mean $\pm$ *SD* of total weight lifted (kg) during bench press repetitions to failure at 60% 1RM in caffeine (5 mg·kg^{-1}) and placebo conditions, *$p < 0.05$.

TABLE 1. Mean ± *SD* for reps, weight lifted, PHR, PBLa, and RPE after bench press repetitions to failure at 60% 1RM in caffeine (5 mg·kg^{-1}) and placebo conditions.*

	Caffeine	Placebo	*p*
Reps	22.4 ± 3.0	20.4 ± 3.4	0.031
Weight lifted (kg)	1,147.2 ± 261.4	1,039.4 ± 231.7	0.027
PHR (b·min^{-1})	164.7 ± 17.5	157.2 ± 16.9	0.0001
PBla (mmol·L^{-1})	7.22 ± 0.83	6.53 ± 0.94	0.002
RPE	7.5 ± 0.66	7.7 ± 0.72	0.082

*PHR = peak heart rate; PBla = peak blood lactate; RPE = rating of perceived exertion.

condition compared to the placebo condition (Figure 2). Likewise, PHR ($t[12] = 5.518$, $p = 0.0001$, Partial $\eta^2 = 0.772$) and PBla ($t[12] = 3.896$, $p = 0.002$, Partial $\eta^2 = 0.536$) were also significantly higher after caffeine ingestion compared to placebo. However, there were no significant differences in RPE scores across conditions ($t[12] = -1.897$, $p = 0.082$, Partial $\eta^2 = 0.357$). Mean ± *SD* for reps, weight lifted, PHR, PBLa and RPE across conditions are presented in Table 1.

With respect to mood state, results from 2 × 2 ways, repeated measures ANOVAs for each BRUMS subscale indicated no significant main effects of interactions for the Anger, Confusion, Depression and Tension subscales ($p > 0.05$). There was a significant main effect for condition for the vigor BRUMS subscale ($F[1,12] = 18.571$, $p = 0.001$, Partial $\eta^2 = 0.595$) with scores for vigor being greater in the presence of caffeine than placebo. Mean ± *SD* of scores on the vigor subscale were 50.1 ± 6.8 and 45.1 ± 7.9 in the caffeine and placebo conditions, respectively.

There were also significant main effects for condition ($F[1,12] = 5.4$, $p = 0.04$, Partial $\eta^2 = 0.359$) and pre to post ($F[1,12] = 18.4$, $p = 0.001$, Partial $\eta^2 = 0.629$) for the fatigue BRUMS subscale. Mean ± *SD* values revealed that scores for fatigue were lower in the presence of caffeine compared to placebo (44.4 ± 3.9 vs. 46.8 ± 5.8) and that fatigue scores were significantly greater post bench press exercise to failure compared to pre exercise (48.1 ± 4.4 vs. 43.2 ± 4.6).

DISCUSSION

This study sought to effect of acute caffeine ingestion on resistance exercise to failure, and on RPE and mood state pre to postexercise in a sample of moderately trained men. The results of this study provide support for prior assertions that acute ingestion of caffeine enhances performance in short-term, high-intensity exercise performance and specifically short-term resistance exercise to failure. This agrees with a range of previous studies (24,27,40) and is in contrast to those studies that have reported no significant enhancement of resistance exercise performance after acute caffeine ingestion (7,29,39). It is also contrary to research by Goldstein et al (22) that examined the efficacy of acute

caffeine ingestion on bench press repetitions to failure at 60% 1RM in trained women. The discrepancy between this study and prior studies by Jacobsen and Edwards (29), Beck et al. (7), and Williams et al. (39) may be for a number of reasons. Notably, Beck et al. (7) employed a caffeine bolus equating to 2.5 mg·kg^{-1} in untrained men. The volume of caffeine administered in this study was double that of the load used by Beck et al (7). To date, the literature pertaining to the effect of caffeine ingestion has suggested the dose of caffeine that results in performance enhancement to be from 2.5 to 7 mg kg^{-1} in both endurance-based exercise and short-term exercise (3,23). As a result, the caffeine load used by Beck et al. (7) may not have been sufficient to elicit an ergogenic effect in their study. Likewise, in both the studies by Beck et al. (7) and Jacobsen and Edwards (29), the participant groups were untrained. This may, at least in part, explain why the results of this study do not agree with those of Beck et al. (7) and Jacobsen and Edwards (29) and are in closer agreement with prior studies that have used trained participants (4,5). The participants in this study were moderately trained team games players. Although they were not competing at an elite level, the participants were training on average 5 times per week and were competent and familiar with resistance exercise generally and bench press exercise specifically. Recent work by Woolf et al. (40) examining the effect of caffeine ingestion on Wingate anaerobic test performance and resistance exercise performance suggested that the mixed results in previous studies might be because of the range of training statuses employed by prior authors. Currently, there is no consensus as to the impact of training status on the effect of caffeine ingestion on exercise performance (41). Future research would therefore be useful in examining this issue further.

Values for PBla are consistent with prior research on the impact of caffeine ingestion on the blood lactate response to exercise performance in aerobically (8) and anaerobically based exercise tasks (40). Elevated PBla values found in the caffeine condition are not unexpected and are similar to other studies of the effect of caffeine ingestion on other modes of performance (2,11). There have been some suggestions for this increase. Researchers have suggested that increased free fatty acid availability reduces lactate production (18) and if lactate use is to occur, pyruvate metabolism must occur quickly (21). Graham (23) has commented that caffeine may inhibit pyruvate oxidation which inhibits lactate use but increases lactate production. Lactate accumulation also builds up in the working muscles which causes a decrease

in intracellular pH (11). This in turn disturbs muscle contractile properties and the activity of glycogenolytic enzymes. Bridge and Jones (11) have noted that this seems paradoxical considering that performance is actually enhanced. They also suggest that an alternative theory may be that caffeine promotes increased adenosine triphosphate (ATP) resynthesis through anaerobic glycolysis enabling more rapid energy provision by increased activity of phospofructokinase or an increased efflux of H^+ from the muscle cell (34). Moreover, Anselme et al. (2) suggested that the calcium released into the sarcoplasmic reticulum during muscular contraction which activates the enzymatic transformation of the glycogen phosphorylase 'b' to the 'a' form. This accelerates glycogenolysis and produces pyruvic acid. Because of the intense nature of the exercise protocol in question, oxidation of pyruvate is limited, and therefore, the formation of lactate increases. Although the increased lactate levels seen in this study suggest a metabolic response, it is possible that the underpinning cause of this is through caffeine's action on skeletal muscle (2,11).

Likewise, PHR data agree with those of prior research on the effect of acute caffeine ingestion on resistance exercise performance (5,24) and also suggest that RPE was no different in the presence of caffeine or a placebo solution. This supports a number of prior studies that have similarly reported no difference in RPE after caffeine ingestion in resistance exercise (4,24,40) However, this also contradicts a wide range of prior research that has reported dampened RPE with caffeine ingestion in aerobically based exercise tasks (14,15). This finding may be because the very short nature of the exercise employed in this study is insufficient to elicit a perceived difference in exertion irrespective of the substance consumed or may be because of difficulties in accurately assessing RPE in short-term, high-intensity resistance exercise. In this instance, RPE was assessed postexercise because of the challenges of recording RPE during bench press exercise to failure. In this instance, RPE may therefore be more reflective of postexercise perceptions of exertion rather than the perception of exertion of the exercise bout itself.

Furthermore, the traditional double blind design used in studies evaluating the effect of an ergogenic aid on performance has been criticized (8). Because comparing an active substance (e.g., caffeine) to a placebo assumes that the placebo is inert, studies using this design may mask the true effect of a given substance. It is possible that the belief that an active substance has been ingested is sufficient to alter an individual's perception of exertion (8,17). Beedie and Foad (8) further suggested that future researchers should employ a third condition in experimental designs where no substance is consumed to determine a baseline from which exercise responses post substance ingestion can be more fully examined. This form of protocol might be useful in future studies to more fully determine the impact of caffeine ingestion during or postexercise on ratings of perceived exertion.

The results in regard to mood state broadly indicate that there were positive main effects for vigor and fatigue subscales of the BRUMS in the presence of caffeine compared to placebo. Specifically, participants reported that they felt more vigorous and less fatigued in the caffeine condition. Following recommendations from a systematic review on the effect of acute caffeine ingestion on high-intensity exercise performance (3), mood state was assessed in this study 60 minutes pre and immediately post each exercise bout. Prior research examining the impact of caffeine ingestion on mood state has predominantly examined postexercise mood state (24) making it difficult to compare the results of this study to those of prior research. As no significant substance $\times$ time interactions were evident for any of the mood state subscales, this study seems to suggest that mood state responses were more a function of the substance ingested than the exercise bout performed by participants. Furthermore, in the article by Green et al. (24), there was no significant difference in feelings of fatigue, post resistance exercise, between caffeine and placebo conditions. On face value, this conflicts with the results presented in this study in respect to fatigue. However, Green et al. (24) did note that feelings of fatigue were 5% lower in the caffeine condition compared to the placebo condition. In the research by Williams et al. (39), participants similarly reported reduced feelings of fatigue (using a 5 point Likert scale) in their caffeine and ephedra trial compared to the placebo trial. Likewise, Duncan (16) reported that the change in feelings of fatigue, although not significant, was less after caffeine ingestion than placebo, pre to post Wingate anaerobic test performance in 6 male and 6 female student athletes. Taken collectively, these prior studies would add partial support to the findings of this study. However, because of the dearth of studies investigating the impact of caffeine ingestion on mood state responses to exercise, further research is needed to fully elucidate the nature of any mood state changes that arise because of caffeine ingestion and after short-term, high-intensity exercise. In this study, mood state was assessed before ingestion of caffeine and postexercise to compare the effect of caffeine ingestion on the mood state response to exercise. This was to ensure that any change in the dependent variables of interest (BRUMS subscales) was as a result of the exercise task to failure with either caffeine or placebo ingestion. However, future studies should consider assessment of mood state post–caffeine ingestion but immediately before any exercise task. In this way, the effect of ingestion of the substance ingested alone could also be examined.

In addition, this study does have a number of limitations. The resistance task employed was brief and may not be fully representative of the range of resistance exercises undertaken by athletic populations. The bench press to failure task was employed in this study to examine the effect of caffeine ingestion (independent variable) on muscular strength endurance (bench press exercise to failure), physiological responses (Bla, PHR), RPE and changes in

mood state (all dependent variables). This testing modality was employed to provide congruence with a range of prior studies that have also assessed the effect of caffeine on resistance exercise performance (3,5,7,22,39) and providing a means to examine the effect of the independent variable on the dependent variable in a controlled manner. The lower amount of muscle used during the bench press, even when performing the exercise to failure, is likely to be much different from a full body workout. As yet, researchers do not appear to have examined the effect of caffeine ingestion on resistance exercise performance typical of that experienced during a regular gymnasium-based training session. Future research might therefore benefit from examining multiple sets of resistance exercise and multiple exercises, rather than 1 set of bench press to failure as is the case in this study. Furthermore, the reason some of the responses to caffeine intake on resistance exercise performance have been contradictory may be because of caffeine sensitivity, prior caffeine use, time of day when experimental conditions have been conducted, hydration status, and overall training level of subjects used. In this study, attempts were made to standardize prior caffeine intake by using moderate caffeine users, to control for and standardize dietary practices preceding testing and to standardize the training status of the subjects selected to participate. However, although subjects were instructed to maintain their normal levels of hydration across experimental conditions, hydration status was not empirically assessed before each condition. This should be a consideration in future research studies. It may also be useful to compare the responses of participants of different training status because this has been suggested as one of the main explanations of the equivocal findings on this topic. Prior authors (16,24,35) have also suggested that caffeine ingestion might also enhance perceptual and psychological responses to resistance exercise including pain perception. It is possible that reduced pain perception, as opposed to dampened RPE, may have played a part in participants' ability to complete greater repetitions to failure in the presence of caffeine in this study. This variable was not examined in this study but could be simply and economically included in future studies of the impact of acute caffeine ingestion of short-term, high-intensity, resistance exercise to failure.

Furthermore, this study examined 1 dose of caffeine on performance. The dose used was in the midrange of caffeine dosages known to be ergogenic. Other studies have shown lower levels (as low as 1.5 mg·kg^{-1}) to be ergogenic in aerobic tasks (33). If lower dosages of caffeine likewise produce enhanced resistance exercise performance, this might be preferable for athletes and coaches to use because it would avoid any unnecessary side effects associated with caffeine ingestion. Research has yet to establish whether lower doses of caffeine produce enhanced resistance exercise performance and whether there is a dose–response curve for this mode of activity.

PRACTICAL APPLICATIONS

Considerable attention has been paid to the use of substances purported to enhance sports and exercise performance. This has included pharmacological agents such as caffeine, and an emerging body of research suggests that acute caffeine ingestion can enhance short-term, high-intensity resistance exercise performance. This study suggests that caffeine ingestion might be of benefit during acute bouts of resistance exercise. Specifically, caffeine ingestion resulted in a better performance on the bench press to failure and positive improvement in the mood state response to exercise compared to placebo. Therefore, coaches and athletes could employ acute caffeine ingestion as a means to enhance performance and achieve greater physiological loading while favorably influencing psychological feelings of fatigue and vigor during resistance exercise.

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