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## Placebo Effects of Caffeine on Short-Term Resistance Exercise to Failure

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**Purpose:** This study examined the placebo effect of caffeine on number of repetitions (reps), rating of perceived exertion (RPE), blood pressure (BP), and peak heart rate (PHR) during resistance-training exercise with repetitions (reps) performed to volitional failure. **Methods:** Following determination of 1-rep maximum in single-leg leg extension, 15 males performed reps to failure at 60% 1-RM in 3 conditions: control, perceived caffeine condition, and perceived placebo condition presented in a randomized order. Participants were informed they would ingest 250 mL of solution that contained either 3 mg·kg<sup>-1</sup> caffeine or 3 mg·kg<sup>-1</sup> placebo 1 h before each exercise trial. A deceptive protocol was employed and subjects consumed a placebo solution in both conditions. During each condition, total reps, RPE for the active muscle and overall body, and PHR were recorded. **Results:** Subjects completed 2 more reps when they perceived they had ingested caffeine. RPE was significantly ( $P = .04$ ) lower in the perceived caffeine and control conditions and RPE for the active muscle was significantly higher across all conditions compared with RPE for the overall body. No substantial differences were evident in PHR across conditions. **Conclusions:** Results of this study are similar to studies of actual caffeine ingestion. However, the perception of consuming a substance that purportedly enhances performance is sufficient enough to enable individuals to complete a greater number of reps to failure during short-term resistance exercise.

**Keywords:** strength, ergogenic, RPE, leg extension, expectancy effect

The placebo effect is a favorable outcome arising purely from the belief that one has received a beneficial treatment.<sup>1</sup> A wide range of studies have documented placebo effects in various domains including psychology and medicine. Although the placebo effect influences physiological and psychological variables,<sup>2</sup> only recently has it been examined systematically in sport and exercise, with findings suggesting it is associated with improved performance.<sup>1,3,4</sup> Clark et al<sup>1</sup> reported a 3.8% increase in mean power in a 4-km time trial when cyclists were told they had received a carbohydrate solution. Likewise, Beedie et al<sup>3</sup> reported that cyclists, completing a 10-km time trial, produced 1.4% less power, and 1.3% and 3.1% greater power when they believed they had ingested 0 mg·kg<sup>-1</sup>, 4.5 mg·kg<sup>-1</sup>, and

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9 mg·kg<sup>-1</sup> caffeine respectively. They concluded that participants consuming a substance thought to be caffeine produce greater power than at baseline. Semi-structured interviews revealed that the cyclists perceived caffeine symptoms and direct effects on performance as a result of consuming what they thought was caffeine. More recently, an electronic survey<sup>4</sup> of 48 competitive athletes revealed that the majority of respondents (97%) believed that the placebo effect exerted an influence on performance and 73% had experienced a placebo effect that positively influenced their performance. In addition, Foad et al<sup>5</sup> found that power output during a 40-km cycling time trial improved by 3.5% over baseline when participants had consumed caffeine, whether they knew they were receiving caffeine or not. However, the belief that caffeine had been ingested resulted in a 2.6% increase in performance in the absence of caffeine.

The placebo effect is a potentially important issue relevant to performance as nutritional supplementation is widely used in recreational and competitive sports settings. In the case of caffeine ingestion, multiple studies have demonstrated enhanced performance in aerobic activities<sup>6-10</sup> and reduced ratings of perceived exertion (RPE) during exercise.<sup>11</sup> More recently, studies on caffeine consumption have focused on its impact on short-term exercise or resistance exercise. Astorino et al<sup>12</sup> reported an 11% and 12% increase in total weight lifted at 60% of 1 repetition maximum (1RM) to failure during the bench press and leg press after caffeine consumption compared with placebo. Similarly, Beck et al<sup>13</sup> reported greater 1RM values for bench press after caffeine consumption. Green et al<sup>14</sup> reported that caffeine consumption resulted in a greater number of repetitions and higher PHR during the third set of leg press to failure at 10RM: these authors concluded that caffeine has an ergogenic effect during short-term anaerobic performance without alterations in feelings of acute fatigue (RPE).

Some research on ergogenic effects of caffeine on short-term resistance performance has limitations. Notably, in previous studies,<sup>12,14,15</sup> participants have completed both a placebo and caffeine consumption condition, in which the placebo serves as a control to examine the impact of caffeine on performance. This is problematic if, as research suggests, simply administering a placebo can enhance exercise performance,<sup>3</sup> the improvement due to caffeine may be masked if comparing to a placebo instead of a control condition. Even though these studies (and many others) used a double-blind design, the fact that participants and investigators are unaware which substance they are consuming does not alter the assumption that the placebo condition is inactive (ie, that it will not have an effect) or that an active substance may act differently when participants believe they have ingested it than when they believe they have not.<sup>5,16</sup> Even in a double-blind research design, the process of consuming a substance may lead to some form of expectancy or active searching for performance-enhancing symptoms. The fact that these studies<sup>12,14,15</sup> did not include a control condition (ie, without consumption of any substance) does not account for these assumptions.

Research on short-term resistance exercise has not considered whether it is the expectancy of the effect of caffeine that causes an improvement in performance rather than the caffeine itself. No previous studies have examined the placebo effect of caffeine during short-term, high-intensity resistance exercise. The aim of this study was to examine placebo effects of caffeine on short-term resistance exercise.

## Method

### Subjects

Following institutional ethics approval and informed consent, 12 males (mean age  $\pm$  SD =  $22.7 \pm 6.0$  years) volunteered to participate. All participants had experience performing resistance exercise and were free of musculoskeletal pain or disorders. All participants were asked to refrain from vigorous exercise and maintain normal dietary patterns in the 24 h before testing and not to consume caffeine after 6:00 PM the night before testing to control for the effects of caffeine already consumed.<sup>17</sup>

### Design

This study employed a within-subjects repeated measures design. Participants were informed they were participating in a study examining the impact of caffeine ingestion on resistance exercise performance. Subjects were told they would consume two solutions, presented in a random order, one containing  $3 \text{ mg}\cdot\text{kg}^{-1}$  caffeine and one containing a placebo. In accordance with protocols used previously, before the performance trials, and with the aim of catalyzing or reinforcing beliefs about caffeine, participants were provided with literature reviewing the findings of published research into caffeine and resistance exercise.<sup>3</sup>

### Procedure

Each participant attended the human performance laboratory on three occasions. All testing took place between 9:00 AM and 12:00 PM and 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 1-repetition maximum (1RM) on the single leg extension. All participants had experience performing resistance exercises in general and leg extension exercise in particular. Before commencing the 1RM, the unilateral leg extension was demonstrated to each participant. Each participant also performed 8 to 10 unweighted unilateral leg extensions before the experimental protocol. The 1RM was determined according to methods advocated by Kraemer, Ratamess, Fry, and French.<sup>18</sup> The 1RM value was used to set the 60% 1RM intensity undertaken during the proceeding experimental trials.

During each condition participants undertook a 5-min submaximal warm-up on a cycle ergometer and completed one set of single-leg leg extension exercise to failure at 60% 1RM. Conditions were presented in a randomized order and were separated by 24 to 72 h. One condition was used as a control trial and involved no consumption of any substance. In the other two conditions, participants were informed they would consume either  $3 \text{ mg}\cdot\text{kg}^{-1}$  caffeine or a placebo diluted into solution on a randomly assigned basis. However, a deceptive administration protocol<sup>1,5,16,17</sup> was employed whereby participants only consumed 250 mL of artificially sweetened water drink 60 min before each exercise trial. In the case of the current study, neither the participants nor the researchers administering the solutions were made aware of the true nature of the research (or content of the

solutions) until the study had ended. Each solution was presented to participants in an opaque sports bottle to prevent the researchers and participants from actually seeing the solutions themselves.

## Lifting Procedures

Leg extension exercise was performed for the dominant leg using a Nova leg extension machine (Nova Inc, United Kingdom) in accordance with protocols described by Earle and Baechle.<sup>19</sup> A trained researcher 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 bpm. This cadence resulted in one complete repetition every 4 s with concentric and eccentric phases comprising 2 s each. The actual mass lifted during each condition was screened from participants during all trials using a purpose-built board slotted in front of the weight stack. Feedback related to lifting procedures or the number of repetitions completed was not made available to participants until completion of all procedures.

## Performance Measures

During each condition, repetitions were counted using a hand tally counter (Tamaco Ltd, Japan) and peak heart rate assessed using heart rate telemetry (Polar Electro Oy, Kempele, Finland). Studies of PHR report no substantial differences between upper and body resistance exercise matched for intensity<sup>24</sup> and used PHR as a measure of physiological strain during leg extension exercise to failure specifically.<sup>20,21</sup> Systolic and diastolic blood pressure were assessed immediately after exercise using automated sphygmomanometry (Omron 509, Omron Healthcare, Inc, Illinois, USA). Total weight lifted was calculated by multiplying the mass lifted by the number of repetitions completed. Immediately after each participant had reached failure, they were asked to provide an undifferentiated (RPE for the overall body, RPE-O) and a differentiated (RPE for active muscle, RPE-AM) rating of perceived exertion using the Borg 6 to 20 RPE scale.<sup>22</sup>

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 to provide an explanation for their decision. 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." Participants were then asked, "Please could you explain why you believe this to be the case" and "Are there any other reasons why you think this was the case." The response to the first question was also used to allocate trial to condition. Following completion of all conditions and each participant's explanations, participants were thoroughly debriefed as to the true nature of the study.

## Data Analysis

Changes in total repetitions completed, total weight lifted, systolic and diastolic blood pressure, and peak heart rate were analyzed using one-way repeated mea-

tures ANOVA. Changes in RPE were analyzed using a 3 (Condition)  $\times$  2 (RPE Region) repeated measures ANOVA. Post hoc analysis using Bonferroni adjustment was performed where any significant interactions and main effects were found. Partial  $\eta^2$  was also calculated as a measure of effect size. A  $P$  value of 0.05 was used to establish statistical significance and the Statistical Package for Social Sciences (SPSS, Inc, Chicago, Ill) Version 15.0 was used for all analyses.

## Results

There were significant differences in the total repetitions completed ( $F_{2,28} = 22.33$ ,  $P = .001$ , partial  $\eta^2 = .615$ ) and total weight lifted ( $F_{2,28} = 18.11$ ,  $P = .01$ , partial  $\eta^2 = .564$ ) across conditions. Participants completed significantly more repetitions (mean difference = 4.1) and lifted more weight (mean difference = 139.1) when they believed they had consumed caffeine compared with the control condition and when they thought they had consumed placebo (mean difference = 72.1). However, there was no significant difference in systolic blood pressure, diastolic blood pressure, or peak heart rate across conditions. Repetitions, total weight lifted, diastolic and systolic blood pressure, and peak heart rate across conditions are shown in Table 1.

In relation to RPE, results indicated that RPE was significantly higher during the trial where participants believed they had consumed placebo compared with when participants perceived that they had consumed caffeine and during the control condition ( $F_{2,28} = 6.61$ ,  $P = .04$ , partial  $\eta^2 = .321$ ). Mean  $\pm$  SD for RPE was  $13.8 \pm 1.9$ ,  $14.2 \pm 1.6$  and  $14.9 \pm 1.6$  for the control, perceived caffeine, and perceived placebo conditions respectively. RPE for the active muscle was also significantly higher than RPE for the overall body across trials ( $F_{1,14} = 54.8$ ,  $P = .001$ , partial  $\eta^2 = .797$ ). Mean  $\pm$  SD of RPE was  $16.2 \pm 1.7$  and  $12.4 \pm 1.6$  for the active muscle and overall body respectively. A significant Condition  $\times$  Region RPE interaction ( $F_{2,28} = 4.96$ ,  $P = .01$ , partial  $\eta^2 = .262$ ) indicated that RPE for the overall body was similar across all conditions, but that RPE for the active muscles was elevated during the perceived placebo condition compared with the control and perceived caffeine conditions (see Figure 1).

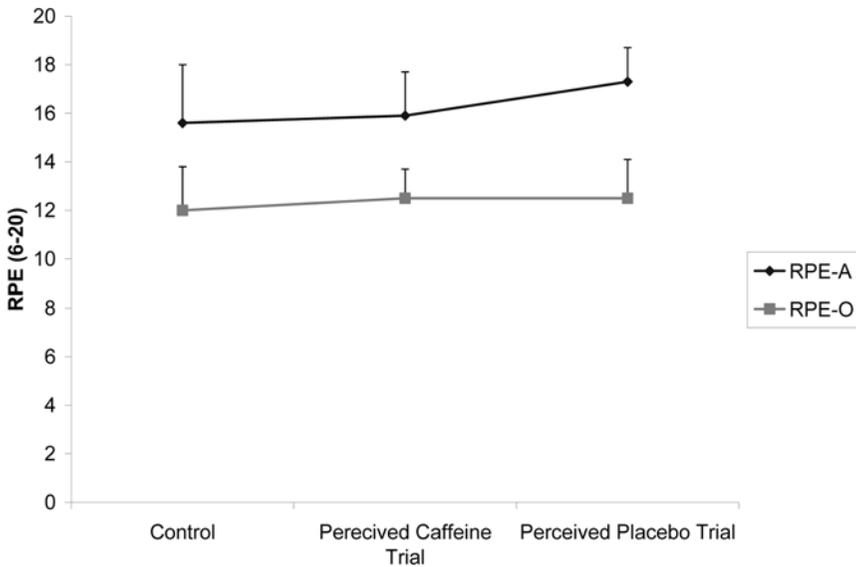
Thirteen of the fifteen participants indicated that they expected caffeine to have a positive effect on their performance. Five of the participants reported direct effects of caffeine on performance (three of these participants also reported performance-related effects).

## Discussion

When individuals consumed a substance that they believed to be caffeine they completed more repetitions to failure and lifted more weight than when they had consumed a substance they believed to be placebo. These results support the findings of studies that have examined the placebo effect during aerobically based exercise tasks<sup>1,3</sup> and are consistent with studies that have examined the impact of caffeine consumption on resistance exercise.<sup>12,14</sup> The RPE results are consistent with other studies that also reported dampened RPE during exercise when caffeine was consumed compared with placebo.<sup>11</sup> In the current study, this dampen-

**Table 1 Repetitions, total weight lifted, systolic and diastolic blood pressure, and peak heart rate across conditions (mean  $\pm$  SD)**

	Control		Perceived Caffeine Trial		Perceived Placebo Trial	
	M	SD	M	SD	M	SD
Total repetitions	16.4	4.1	20.3	4.6	18.3	4.1
Total weight lifted (kg)	576.9	100.8	713.8	120.8	655.5	154.5
Systolic blood pressure (mm Hg)	132.8	13.1	140.3	11.2	135.8	10.1
Diastolic blood pressure (mm Hg)	69.75	13.4	69.6	17.5	69.0	13.8
Peak heart rate (BPM)	138	12.4	145.6	14.9	139	19.1



**Figure 1** — RPE for the active muscle (RPE-A) and overall body (RPE-O) across conditions (Mean  $\pm$  SD).

ing appears to specifically act on feelings of exertion in the active musculature. However, in both the main effect for RPE and the significant Condition  $\times$  RPE region interaction, RPE values were significantly greater in the perceived placebo condition in comparison with the control and perceived caffeine conditions. However, the absence of significant differences between control and perceived caffeine conditions implies that the belief that an ergogenic substance has been administered was not sufficient to influence perception of exertion. In this respect, a negative (or nocebo) effect may have occurred. Negative beliefs about consumption of a substance may elicit a negative, or nocebo, effect where performance is poorer than baseline performance.<sup>2,3</sup> In this case, it may be that the placebo effect manifests itself in increased effort. Further, larger scale study of this issue is needed to clarify this finding.

Eighty-three percent of the participants in the current study expected caffeine to have an effect on performance. This observation is important as the exact mechanisms by which caffeine exerts its ergogenic effects are still unresolved.<sup>13</sup> Although several physiological mechanisms have been proposed,<sup>9,24</sup> it appears that simply informing an individual that they will be given a performance-enhancing substance can improve performance. This finding is consistent with other studies of the placebo effect.<sup>2,6</sup>

It is not known whether the placebo effect is manifest as a direct effect on performance, or whether the participant becomes more aware in searching for caffeine-related symptoms, which leads to changes in performance strategy. As there was no significant difference in peak heart rate across conditions in the current study, we consider that the level of physiological strain was similar. Despite this, it is possible that performance on the task used in the current study may be

limited by local muscle endurance rather than cardiovascular factors. Another possibility is that the unilateral leg extensions were not sufficient to elicit large changes in heart rate. Future research on this topic might use other means to monitor physiological load or strain when using leg extension exercise to failure.

All participants in the current study reported either caffeine-related symptoms or performance effects of caffeine. Some participants reported both, while others reported only caffeine-related symptoms. It is logical to assume that some participants monitored their own performance as a means to obtaining some feedback on their performance. The researchers sought to minimize this possibility by shielding the mass that each participant lifted: there was no pattern in the trials that were identified as the “perceived caffeine” and “perceived placebo” trials. Eight of the participants identified their second trial in which they had consumed a solution as the trial where caffeine had been consumed, with seven participants identifying the first trial as this condition. However, this shortcoming should be considered as a limitation of the current study and future research should control for performance feedback more effectively. The lack of controls for learning effects should also be taken into account in future work. Although the postexperimental questioning was brief it appears that a form of belief was involved. Congruent with other studies of the placebo effect,<sup>1,3</sup> it is possible that these beliefs result in modification of psychological processes such as expectancy, belief, or arousal. Future research should benefit from using a more in-depth postexperimental interview to fully elucidate these issues.

There are a number of limitations of experimental research that has examined the placebo effect. This study, and other placebo effect studies in the sport and exercise setting,<sup>1,3,5</sup> have typically been laboratory based and whether placebo effects are artifacts of the research setting that would be overridden in real-world settings is unclear.<sup>16</sup> Furthermore, previous experimental studies have tended to assume that the placebo effect is static and any placebo effect is positive compared with baseline performance.<sup>23</sup> A placebo effect might exert a negative influence on performance<sup>21</sup> as might be the case in respect to RPE values reported in this study. Finally, use of a deceptive administration protocol is predicated on the fact that participants are told that they will be taking a particular substance and so the experimental data are not truly blind. Foad et al<sup>5</sup> have used the double disassociation design to examine placebo effects. This may merit consideration by future researchers interested in this topic.

The placebo effect may not be the only explanation for the findings of the current study. Low a priori expectations of performance in the perceived placebo condition or because of the motivational climate fostered by the situation may be a factor. If a performer had low expectations in the condition that they believed was the placebo condition, any difference in performance between the perceived caffeine and perceived placebo trials may have been magnified. Personality characteristics may predispose an individual to respond to a placebo.<sup>25</sup> Future research should address issues of personality, motivational climate, and responsiveness when examining placebo effects.

## Practical Applications

Considerable attention has been paid to the use of substances purported to enhance sports and exercise performance. This work has included pharmacological agents such as caffeine. There is a placebo effect of caffeine that can provide a performance benefit during an acute bout of short-term resistance exercise to failure. In this case it appears that the belief that a substance that might enhance performance has been ingested was sufficient to improve performance. Coaches and trainers could benefit by utilizing the placebo effect within exercise settings to enhance resistance exercise performance.

## Conclusions

The perception that consuming a substance will enhance performance is sufficient to enable individuals to complete a greater number of repetitions compared with control or perceived placebo conditions. The exact mechanism of this placebo effect is unknown and further investigation of this issue is warranted. A greater range of physiological responses in the placebo effect that examine the time course of the placebo effect in exercise settings is indicated.

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