

**Caffeine Potentiates the Ergogenic Effects of Creatine**

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ABSTRACT

Jerônimo DP, Germano MD, Fiorante FB, Boreli L, Neto LVS, Souza RA, Silva FF, Moraes AC. Caffeine Potentiates the Ergogenic Effects of Creatine. **JEPonline** 2017;20(6):66-77. The aim of this study was to determine the effect of caffeine on creatine supplementation on electromyographic activity and torque. Sixteen males were supplemented with caffeine (6 mg·kg⁻¹) and creatine (3 g). They did the knee extension test on the isokinetic dynamometer while electromyographic activity was monitored. The caffeine group achieved 4.57% increase in EMG activity and 4.25% increase in torque. The creatine group achieved a 17.07% decrease in the EMG activity and a 3.45% increase in torque. The caffeine and creatine group achieved a 3.07% increase in EMG activity and a 5.79% increase in torque. The findings indicate that the consumption of caffeine at 6 mg·kg⁻¹ in association with 3 g of creatine for 7 days generated a significant improvement in performance, increased the production of torque, and improved the EMG muscle activity. Thus, it is more than reasonable to conclude that caffeine potentiates the effects of creatine during a physical exercise.

Key Words: Creatine, Caffeine, Dietary Supplements, Performance

INTRODUCTION

Recently, the consumption of food supplements have become highly diffused and adopted by athletes and sportsmen in search for an improvement in physical performance and for the general individual health. These food supplements are characterized as ergogenic aids that enhance energy production and, therefore, provide athletes with a competitive advantage. The term is derived from two Greek words: “ergon” (work) and “gennan” (produce)

Several studies indicate the benefits generated by the supplementation (32,43,47), among others that indicate the ingestion of food supplements can reduce the athletes' fatigue (13,20) and injury level, as well as optimizing energy for muscular work and promoting a faster recovery (3,19). As a result of these physiological benefits, there is a bigger demand and consumption for these products.

Among the many available substances on the market, two of them are distinguished from the others. They are caffeine and creatine. These substances are responsible for the largest sale of performance-enhancing supplements during the last several years (10,13). In 2000, creatine was estimated by the American College of Sports Medicine to have reached a world consumption of 2500 tons (13). Clearly, the supplement market is growing each year as a result of the use by professional athletes (42). Yet, neither caffeine nor creatine is currently on the list of banned substances of any sports federation (2,41). More research is needed to better determine the effects of these substances on physical performance.

Creatine (Cr) plays an important role in the fast energy supply during the muscle contraction. It is involved in the transfer of a phosphate group from the phosphorylcreatine (Pcr) to ADP to regenerate adenosine triphosphate (ATP) through a reversible reaction catalyzed by kinase phosphorylcreatine kinase (PCK) (16,40). Physiologically, the Cr is predominantly used by tissues with higher energy demand (13,19). The main location for Cr storage is in the skeletal muscle tissue, which is ~95% of the body's Cr (16,42).

Since the 1990s, creatine supplementation has been an ergogenic resource in sports to help increase the athletes' performance (27) due to a reduction from the muscle protein degradation, an amplification in the increase of the protein synthesis, and/or indirectly as a result of the increase in training load performed as a function of its ergogenic effect (8,19,35). The underlying mechanisms include the increase in mRNA of myosin heavy chain and protein expression (8), increase in liquid nitrogen retention (22,34,39), and anti-catabolic effects in some tissues (34).

The ingestion of caffeine also generates interesting physiological effects on the athletes' physical performance. At the cellular level, caffeine increases the release of calcium from the sarcoplasmic reticulum. This is due to the inhibition of the enzymes, butyrylcholinesterase (BuChE) and acetylcholinesterase (1,29). Both facilitate the contractile response of skeletal muscle (29), blockade of the adenosine receptors, alters the neuromodulation functions from the synaptic transmission and hemostatic (9), increases the intracellular concentration of adenosine-5'-monophosphate (AMP) and cyclic guanosine monophosphate (GMP). This is done by the inhibition from the enzyme hydrolyzer, phosphodiesterase, that activates the protein kinase A (PKA) resulting in the phosphorylation of several cytosolic proteins, which generates a specific cellular response between them and lipolytic activities (4,8,48). Also,

there is the decrease in the cells' sensitivity to insulin that results in a reduction in the glucose storage (17,18).

Caffeine exerts beneficial effects on glucose metabolism through the increase in the uncoupling protein expression and from the lipid oxidation that in turn decreases the diabetes mellitus extension (38). These changes are also subordinate from other components that play an important role (12,17). According to Vandenberghe et al. (36), the interaction between caffeine and creatine can reduce the creatine supply and the pharmacokinetics, which could influence in a negative manner the protein synthesis process, the Caf action in the calcium sarcoplasmic reticulum release is associated with a chronic depletion of intracellular calcium that changes the fatigue process but damages protein synthesis (46). However, this understanding of the antagonistic action between the caffeine and creatine association is being clarified by recent research in animals (10,11,21), Even though, such research is relatively rare in humans. In fact, it is hard to find research that allows for the categorization of the real action on the athletes' physical performance. Hence, the present research is important in order to better understand the influence of these compounds on athletic performance and sports nutrition.

METHODS

Subjects

This study examined 16 physically active subjects 18 and 30 yrs of age. The subjects were not using either anabolic steroids or any nutritional supplements. The test consisted of a protocol that required the subjects to perform 45 reps of knee extension and flexion with a constant angular speed of $120^{\circ}\cdot\text{sec}^{-1}$ on the isokinetic dynamometer Biodex. Torque was monitored in the extension phase along with the subjects' EMG activity from the vastus lateralis (VL), vastus medialis (VM), and rectus femoris (RF). The subjects were submitted to a period of 3 days to become familiarized with the protocol and adaptation to the isokinetic dynamometer as well as the electrodes. Then, the control group (Con = 16) was submitted to the first test. Immediately after the test, the same subjects began the supplementation phase for 3 days that consisted of $6\text{ mg}\cdot\text{kg}^{-1}$ caffeine (Caf) followed by a detox period of 5 days. After the detox period, the subjects began the supplementation with 3 g of creatine (Cr) for a period of 7 consecutive days. At the end of the 7th day the subjects continued to supplement with creatine (3 g), but also supplemented with $6\text{ mg}\cdot\text{kg}^{-1}$ caffeine (CrCaf) for 3 days.

Acquisition of the EMG Signal

The electrical activity of the muscles (i.e., the EMG activity) was recorded by a 16-channels model MP150™ (Biopac System®, USA) eletromyography with sampling frequency of 2000 Hz. The relationship between the differential gains and limits of signal input was established in $\pm 5\text{mV}$. The reference electrode (terra) was placed on the left elbow (lateral epicondyle).

Before the beginning of each test, each subject's skin was cleaned and prepared with a razor, alcohol, and cotton. Just after the active bipolar electrodes model TSD 150™ (BIOPAC Systems®, USA) the rejection was from 95 dB, with distance between the electrodes fixed to 2 cm, the electrodes were fixed in the dominant limb with hypoallergenic adhesive tape (Transpore) on the VL, VM, and RF muscles in accordance with the standardization proposal

by SENIAM (14).

For the capture and processing of signals, the software *AcqKnowledge* 3.8.1™ (BIOPAC Systems®, USA) was used. The integrals EMG signals were submitted to digital filtering using band-pass filter to 20 Hz and 500 Hz and, then rectified and smoothed (moving window of 10 samples). For the analysis of the corresponding EMG signal values, the normalized 5 sec values from RMS (Root Mean Square, μV) were used.

Isokinetic Dynamometer Biodex

An isokinetic dynamometer Biodex Model System 3 (Biodex Medical System, Shiley, NY, USA) was used to determine the torque produced during the maximal voluntary contractions (both concentric and eccentric isokinetic). The subjects were sitting in the chair of the isokinetic dynamometer. They were fixed to the chair with tracks from the trunk, pelvic, and thighs in order to keep the body stable during the maximum effort. The hip and knee were positioned at $\sim 90^\circ$ of flexion (24,33) with the non-tested limb fixed by straps to maintain stability. When the subject was positioned in the isokinetic dynamometer chair, the knee joint axis (lateral epicondyle of the femur) was aligned with the rotation axis from the isokinetic dynamometer mechanical arm.

After the subject was positioned in the chair and before the beginning of the test, the dynamometer was calibrated. The test provided the subject's EMG and at the same time the torque signs, positioning, time of execution, and electrical activity from the evaluated muscle on the computer that was connected to the equipment through the software *AcqKnowledge* 3.8.1™ (BIOPAC Systems®, USA) that allowed for a better interpretation of the data.

Statistical Analysis

The data were extracted and treated in statistical programs where they were analyzed through a One-Way ANOVA. The torque values were quantified and paired through repeated measures ANOVA and Tukey's Multiple Comparison Test to compare the results with the evaluations from different supplementation protocols. Variance analyses (One-Way ANOVA) were used to evaluate and normalize maximum work and maximum torque for muscle fatigue.

RESULTS

Figure 1 shows the values from normalized RMS that were from the EMG of the VL, VM, and RF muscles during the implementation of the knee extension on the isokinetic dynamometer Biodex. A statistically significant difference ($P < 0.05$) was found in the groups. In relation to the Pre group, we observed a greater signal activation in the groups supplemented with caffeine (7,47), which reached higher values compared to the other groups. In relation to the Pre group, the Caf group reached an increase of 4.57% in the EMG activity during the whole work, the CrCaf group reached an increase of 3.07%, and the group supplemented with 3 g of Creatine (Cr) had a significant decrease of 17.07% in the EMG activity.

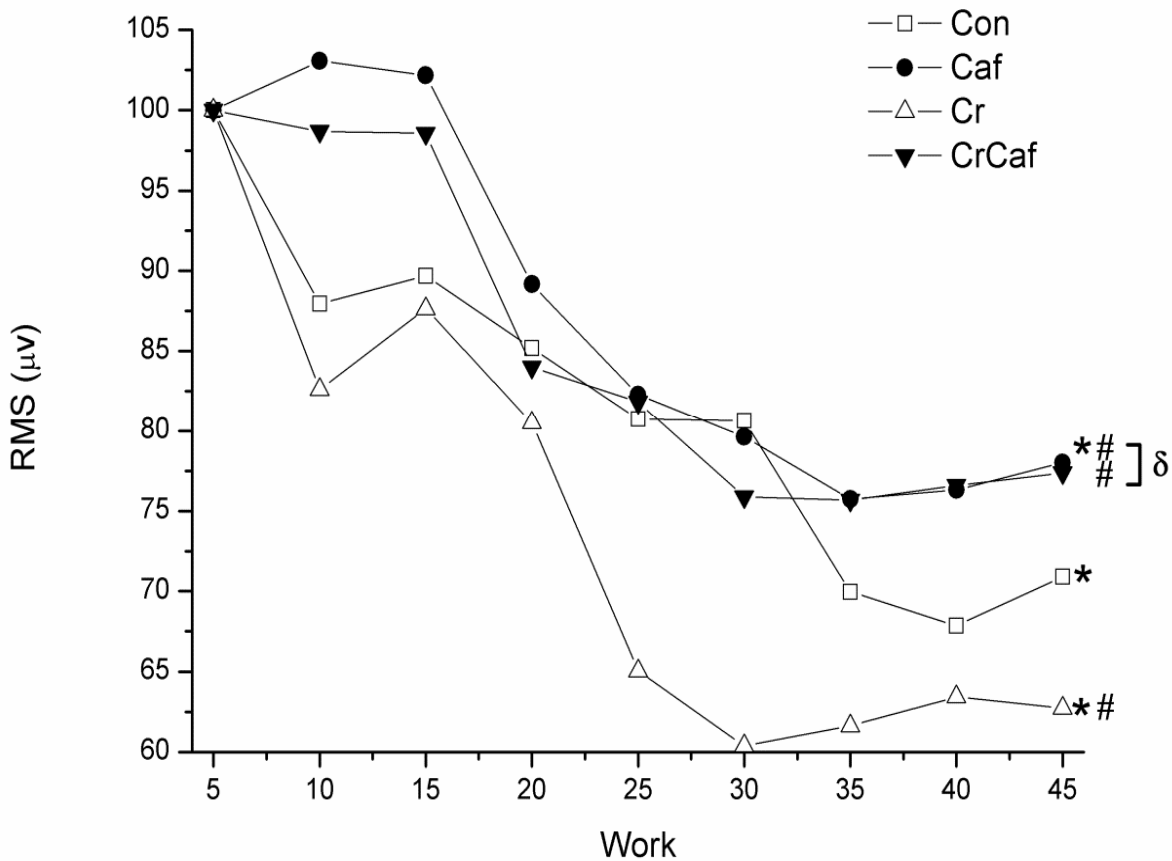


Figure 1. The Normalized RMS Values for the EMG of the VL, VM, and RF Muscles are Presented. *, # Statistically Significant ($P < 0.05$), δ No Significance

In Figure 2A and 2B, the behavior of the curves shows a drop in the work or torque efficiency. For a better visualization of the results, the data for the 45 executions are divided into two parts. Figure 2A is characterized from the beginning of the test to the twenty-fifth (25^a) execution while Figure 2B is characterized from the twenty-fifth to the forty-fifth (45^a) execution of the dynamometer protocol. Note that there is a similar behavior in all the groups tested. These values are consistent with the fatigue pattern generated during the protocols with higher execution numbers and intermediate speed (5,26,28).

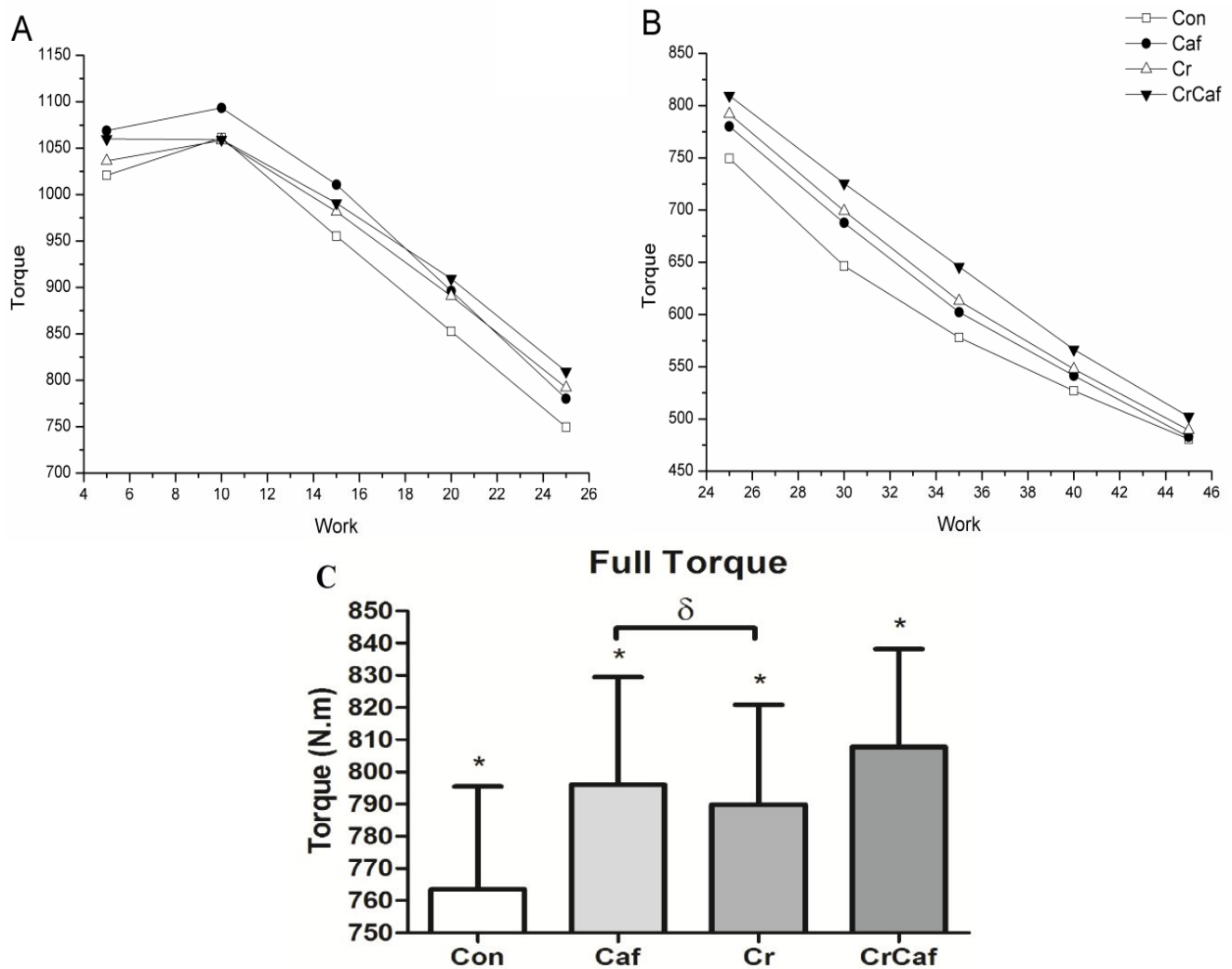


Figure 2. The Torque Behavior Generated from the 45 Executions of Knee Extension on the Isokinetic Dynamometer. Figure 2A is characterized from the beginning of the test to the twenty-fifth (25^a) execution. Figure 2B is characterized from the twenty-fifth to the forty-fifth (45^a) execution ($P < 0.01$). Figure 2C presents the subjects' torque behavior generated during the 45 executions of knee extension on the isokinetic dynamometer ($*P < 0.01$), δ No Significance ($P > 0.05$).

We found an increase of 4.25% in the amount of torque generated by the Caf group, an increase of 3.45% in the Cr group, and 5.79% in the CrCaf group. These values represent the data from the electromyographic activity in Figure 1.

In the Figure 3, the behavior in the peak torque and the fatigue values from % (B) generated during the study are presented. There were no significant differences in these values between the groups, even though there was an interesting decrease in fatigue in the CrCaf group.

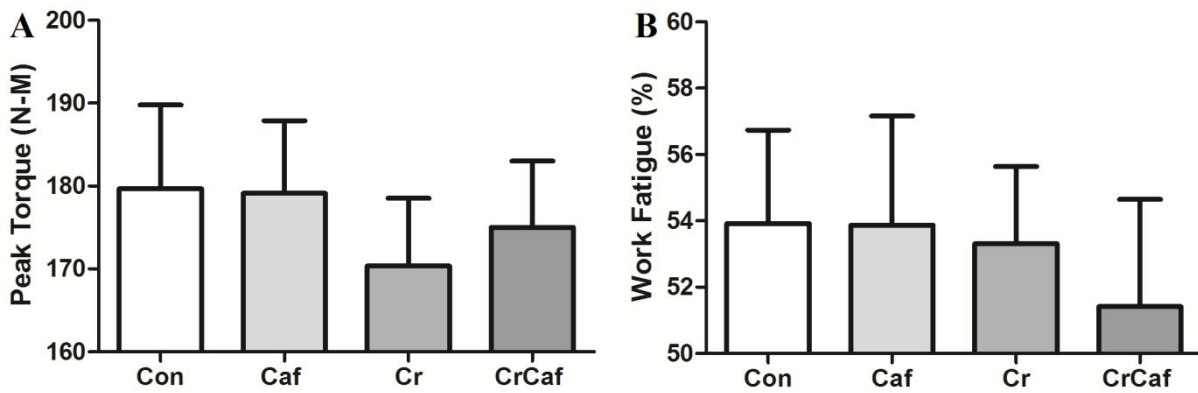


Figure 3. Figure A Presents the Subjects' Peak Torque in Each Group. Figure B Presents the Subjects' Fatigue during the Work on the Isokinetic Dynamometer ($P>0.05$).

Although the subjects' peak torque data and % fatigue do not show significant differences, these findings are complementary and may, therefore, not change the importance of the results in regards to the Cr and Caf supplementation.

Figure 4 presents the comparison of the torque produced in relation to the total time on the isokinetic dynamometer. The findings indicate, while it can be observed that in some groups torque was increased, the time of work was reduced. This finding confirms the effectiveness of the protocol used.

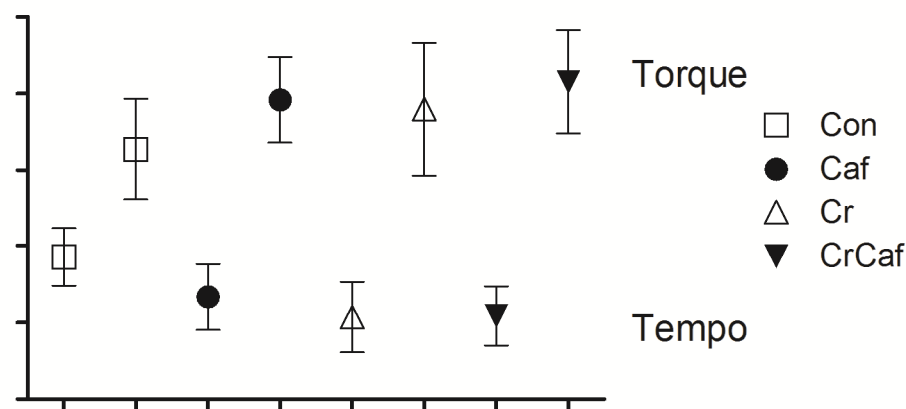


Figure 4. The Correlation between the Torque Produced and the Time for Execution of Work.

DISCUSSION

Figure 1 indicates that the ingestion of caffeine increased the EMG activity in both the Caf group and the CrCaf group. An explanation for this finding is caffeine inhibiting the action of butyrylcholinesterase (BuChe) and acetylcholinesterase enzymes (AChE) (1,6,23).

Another important finding in the present study was that the CrCaf group obtained values in the EMG activity similar to the Caf group. This demonstrates that the association between these two compounds do not interfere with the ergogenic action of one another, which is contrary to some studies (15,45). This finding indicates that this association can inhibit or even eliminate the ergogenic action from the supplementation.

When torque production was analyzed throughout the work (Figure 2), there was a significant increase in torque ($P < 0.01$). This can be explained in the groups supplemented with Cr, given the increase in the PCr concentration by the Cr supplementation in the skeletal muscle tissue. Thus, the increase in PCr improves the subjects' ability to resynthesize ATP (adenosine triphosphate) (13,30). This means PCr provides energy during high-intensity exercise along with the decrease in reliance on anaerobic glycolysis to attend the demand for energy during the maximum workloads (20,31). Also, PCr decreases the concentration in the intramuscular H^+ accumulation while increasing the buffering capacity (10,25,37,44). The result is an increase in the force production force and delay in the onset of fatigue.

Interestingly, the group that achieved greater torque values was the CrCaf group. The subjects achieve an increase of 5.79%, which corroborates with the findings of other researchers in animals (11,21). This indicates that the ergogenic effect is greater due to the combination of Cr and Caf.

Despite the fact that this study found significant values in EMG activity and torque, there were no significant changes in the peak torque and fatigue index (Figure 3) despite the fact that there was a non-significant decrease in the subjects' fatigue of 4.58% in the CrCaf group. In Figure 4, when we correlated the torque produced during the work and the total time that the subjects performed the protocol, the supplemented groups obtained higher values of torque at lower total time, and the group CrCaf in particular got the best correlation torque and time.

This study determined that the ingestion of caffeine improved primarily the EMG activity, and the Cr ingestion improved mainly the rate torque production in the protocol used. However, it is clear that there were better results in both EMG activity and torque production when creatine and caffeine were combined.

Limitations of this Study

A limitation of the present research is the fact that we did not perform tests of dosages of metabolites (such as creatine dosage absorption by the tissue), which may have provided addition information (16). However, this research technique requires costly equipment and acquisition of skeletal muscle tissue for analysis, which is frequently not possible to carry out.

CONCLUSIONS

The findings indicate that there was a significant increase in torque in the supplemented groups with creatine and caffeine. Also, the consumption of $6 \text{ mg} \cdot \text{kg}^{-1}$ caffeine in combination with 3 g of creatine for 7 days generated significant change in the subjects' resistant performance. Thus, the data highlight the fact that the supplementation of both creatine and caffeine does not inhibit the Cr ergogenic effect, but rather potentiates the effect.

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