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ORIGINAL RESEARCH ARTICLE

# Effect of Short-Term Caffeine Supplementation and Post-Activation Potentiation On Fatigue Indices and Anaerobic Power of Professional Wushu Athletes

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## Abstract

**Background** This study aimed to assess the complementary effect of short-term caffeine supplementation along with post-activation potentiation on the fatigue index and anaerobic power of professional Wushu athletes.

**Methods** For this study, 16 professional athletes from Qom province were randomly selected and divided into five groups: PAP (placebo with PAP), placebo, caffeine with PAP, and caffeine. The consumption of caffeine and placebo was in the form of capsules, so that each person was given (6 mg per kg of weight) 60 minutes before the anaerobic running-based test. The PAP groups consisted of four repetitions of the squat movement with an intensity of 70% of 1RM. All groups performed the anaerobic RAST test in every session with an interval of one week. Analysis of variance with repeated measurements was used to assess the differences between groups.

**Results** The results of this study showed that the fatigue index was not significantly different among all groups ($p = 0.45$). The average power in all three post-activation groups showed a significant increase compared to the placebo group ($p = 0.001$). In the comparison between the intervention groups, it was found that this increase in the caffeine group with post-activation was more than in the other groups ($p = 0.001$). It was also observed that the peak power was higher only in the caffeine group with post-activation than in the other groups, and the other groups had no significant difference. In relation to the total time of the RAST test, all intervention groups showed a significant decrease compared to the placebo without post-activation ($p = 0.001$). In the comparison between the peak power, it was found that the increase in the caffeine group with post-activation was more than in the other groups.

**Conclusion** In general, the combination of PAP and caffeine can improve the performance of Wushu athletes.

**Keywords** Caffeine, Fatigue, Athletic Performance, Wushu

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## 1 Introduction

Martial arts hold a unique place among sports nowadays. Wushu, also known as Kung Fu, is an ancient martial art with its roots in China. Currently, there exist numerous variations of Wushu styles. However, in an effort to establish uniformity in rules, techniques, and competition formats, a new Olympic Wushu style has been developed. Olympic Wushu comprises both Taolu and fighting competitions. Taolu competitions involve formal and standardized routines using barehanded, long weapons, and short weapons. Precision, agility, velocity, and strength are key factors in evaluating the movements. On the other hand, fighting competitions have different weight categories for men and women. Wushu combats consist of three two-minute rounds with a one-minute rest, and involve full-contact punches, kicks, and throw techniques. The literature pertaining to combat sports reveals that athletes engaged in grappling with opponents, such as wrestlers and judo athletes, exhibit significantly high anaerobic capacity and strength, along with high or above-average aerobic power, and low body fat levels. On the other hand, athletes who strike opponents, such as karate and taekwondo players, demonstrate high aerobic capacity, flexibility, and above-average anaerobic power and capacity. Olympic Wushu competitions involve a combination of both grappling and striking techniques. According to the above, the performance of Wushu fighters during a competition depends on their ability to maintain and produce high-energy efficiency per unit of time. Time to exhaustion, increased anaerobic power, and improved exercise performance are also considered important characteristics of an athlete.[1]

Various physical conditioning techniques, such as strength training and plyometrics, tailored for combat sports athletes have demonstrated positive outcomes when utilized as a prerequisite for specific movements in fencing and taekwondo. These methods have notably enhanced maximal strength, muscle power, and jumping ability. The purpose of these exercises is to elicit a temporary boost in muscle power before executing a forceful action, a phenomenon referred to as post-activation potentiation (PAP). Today, some scientists have proposed the term PAP in the warm-up phase. Notably, elite taekwondo practitioners have shown significant enhancements in the Frequency Speed of Kicks Test (FSKT) when PAP drills are incorporated with a 10-minute rest period. Many studies demonstrate the immediate effect of maximal and submaximal voluntary contractions on improving muscular strength and jump (vertical and horizontal) performance.[2] The execution of explosive movements is improved after heavy and moderate strength training/resistance exercise.[3] In addition, the degree to which this method is affected depends on various factors, including the methods of performing PAP and specific exercise.[4]

On the other hand, in addition to exercise, it was observed that the habitual and long-term use of dietary supplements might cause a decline in the occurrence of fatigue and the ability to maintain strength during a competition. One of the most widely used supplements in strength and combat sports is caffeine. Caffeine can exert its ergogenic effects in various ways, including reducing reaction time, delayed fatigue, increasing concentration and alertness, increasing recall of fatty acids, increasing $Ca^{+2}$ release from the sarcoplasmic reticulum (SR), improving skeletal muscle contractility, the stimulation of catecholamine secretion, the increase of force production via improved neuromuscular transmission, the enhancement of maximum force output per unit time (explosive power), and the mitigation of fatigue perception.[5]

Caffeine is rapidly absorbed through the intestine, and the amount of its metabolites increases in the blood, usually within 15-45 minutes, and reaches its maximum concentration in the blood within an hour. The effects of caffeine appear less than 1 hour after taking an average dose and disappear after 5 hours. Although caffeine was previously included in the World Anti-Doping Agency (WADA) doping list, it has been removed from the list of banned substances since January 2004.[6]

Research on the ergogenic effects of caffeine has often focused on endurance activities, whose positive effects have been proven in fields such as boating, skiing, cycling, and running. Even though the potential ergogenic effects of caffeine on short-term intense and heavy activities may improve neuromuscular transmission, it is not clear. Moreover, the results of the research conducted on the effect of caffeine on short-term heavy exercises and martial arts are lacking in clarity. For example, in their research on the Wingate test (high-intensity intermittent exercise), Anselme et al. showed that the ingestion of 250 mg of caffeine increased maximal power by 7%.[7] Greer et al showed that peak power and average power increased due to caffeine supplementation. While these researchers did not observe a significant increase in blood lactate levels compared to the control group.[8] Sotiropoulos et al. recorded an increase in blood lactate levels in the supplement group compared to the placebo group. In an activity similar to taekwondo competition,[9] Lopes-Silva et al. observed that caffeine increased the level of participation of the glycolytic system in force production, while no difference was observed with the placebo group regarding taekwondo athletes' performance, perception of fatigue, and parasympathetic activation.[10] Relatively little research has been done on caffeine ingestion in martial arts, especially Wushu, and the results of the effect of caffeine ingestion in intermittent activities are usually generalized to these disciplines. However, similar to high-intensity interval training (HIIT) methods, explosive execution of resistance exercises, as well as concentration and action/reaction times, play a decisive role in martial arts in addition to physical pressure. Accordingly, it is necessary to conduct more extensive research on the effect of caffeine ingestion on martial arts.[11]

As seen in the studies above, both nutritional (caffeine) and exercise (PAP) interventions have led to an increase in athletes' performance in anaerobic power tests; however, findings on martial arts, especially Wushu, are limited. Although Researchers are looking to understand whether combining the two variables could have a synergistic effect. Competition at the professional level is highly sensitive, and even the slightest interference can alter the outcome, potentially affecting the color of the medal. Therefore, the study aimed to investigate the acute effects of caffeine supplementation and PAP on the performance of professional Wushu athletes, both independently and in combination.

## 2 Methods

### participants

This article was extracted from a master's thesis, and the professors approved the issue of ethics in research before the research council approved the proposal. Sixteen professional Wushu athletes participated in this study (men: n = 16, age = 22 ± 3 years, weight = 71.40 ± 8.08 kg, height = 172.33 ± 3.45 cm, and total body fat percentage = 14% ± 1.64%). All participants completed the protocol. The athletes trained for a minimum of 10 hours per week, encompassing both technical and physical conditioning. At the outset of data collection, participants were informed about the study's objectives and the potential risks associated with their participation. They were then asked to provide written consent after being fully informed. Approval for the experimental procedure was granted by the institutional ethics committee. The inclusion criteria were: (a) Wushu athletes with more than four years of experience; (b) those trained two or more times per week; (c) those who participated in national tournaments organized by the National Sports of Wushu of Iran Federation. The exclusion criteria were: (a) any incapacitating illness or injury that prevented their usual physical performance; (b) those who were in a period of physical rehabilitation (c (those with irregular participation in research. They were members of the Qom province, preparing for the 2023 Iran national team selection championship.

### procedures

Participants underwent caffeine supplementation in a double-blind manner; the participants as well as the study personnel, who delivered the capsules to the participants and performed all tests, were blinded to the condition allocation. A laboratory technician, responsible for the preparation of the doses, was the only person aware of the randomization code during the trial. he was not involved in other study functions. A familiarization session was organized to acquaint the participants with the protocol. This session took place one week before the implementation of the protocol, during which the subjects were instructed on the proper method of supplement intake, the one-repetition maximum test, and the correct techniques for weightlifting. This study was designed as a crossover. The subjects were divided into four groups of three and one group of four people. In the first session, each group was placed in an experimental situation. Then, the groups were randomly switched every week, and each group experienced a new problem. They experienced different research states over a one-week interval. After filling out the informed consent form and undergoing medical examination, the subjects experienced five experimental conditions: i) caffeine ingestion and PAP; ii) placebo intake and PAP; iii) caffeine ingestion without PAP; iv) placebo intake without PAP; and v) no caffeine ingestion/placebo intake and PAP. In general, the subjects attended six sessions in the laboratory and similarly experienced the five mentioned conditions in different weeks (with one-week periods between them for washout) in a randomized single-blind manner.[12] Participants were asked about their habitual consumption of any food or beverages containing caffeine. They reported a minimal intake (equivalent to less than two cups of coffee daily). A comprehensive inventory of all caffeine-containing items was compiled and distributed to each participant 48 hours before each experimental phase. Participants were directed to abstain from consuming any items listed, as well as alcoholic beverages, in the 48 hours leading up to each trial. The athletes performed the tests after being hydrated and fed, with the last meal taken 2 hours before the start of the supplementation protocol. They were instructed to record their diet for the 24 hours preceding the first experimental session and to repeat this process before the subsequent experimental sessions.

### Supplementation

Caffeine and a placebo (dextrose) were administered in capsules to each person 60 minutes prior to the test. The dose of caffeine was 6 mg/kg body mass (maximum 400 mg) according to the research background and recommendations. Before starting the supplementation and at the end, athletes completed a questionnaire on gastrointestinal discomfort. The questionnaire comprised 19 questions related to heartburn, dizziness, and headache, which were completed by the athletes attributed values ranging from 1-10, where one is "no problem at all" and ten "the worst it has ever been." The symptoms were considered severe when the score was equal to or greater than five. The subjects were asked if they were able to diagnose what ingested and subjects couldn't able to identify what they ingested.[5]

### Pap intervention

PAP exercise was executed in PAP groups exactly six minutes before the running-based anaerobic capacity test (RAST). The RAST test has previously been used in similar studies to measure the anaerobic power of martial artists.[13] After the general warm-up, the subjects executed PAP by doing exercises designed to raise their heart rate. PAP exercise consisted of four squat repetitions with 70% 1RM. The one-repetition maximum in the familiarization session was calculated based on the Brzycki equation.[14]

Fatigue index, average power, and peak power were measured using RAST. RAST consists of six fast-paced repetitions at a 35-meter distance and maximum severity, with a rest interval of 10 seconds in each repetition. Two referees recorded the time using a stopwatch, with one standing at the beginning and the other at the end of the 35-meter distance. The subjects stand behind the line and start running with maximum intensity after hearing the sound of the horn and crossing the finish line.[1]

### 2.3. Statistical Analysis

Data were tested for normality using Kolmogorov-Smirnov tests. Once normality was confirmed, the Assumptions of the use of Repeated Measures ANOVA, including the homogeneity of variances, were met. Repeated-measures ANOVA was employed to examine the existence of between-group and within-group differences. The Bonferroni post-hoc test was also used to identify statistically significant differences in the results, as well as to determine which averages showed a significant difference. The significance of the tests was considered at the $p \leq 0.05$ level.

## 3 Results

Table 1 presents the mean and standard deviation of the dependent variables, along with the results of the repeated measures analysis of variance. Figure 1, Figure 2, Figure 3 and Figure 4 present the RAST performance variables in the different conditions. The results of this research indicated that there was no significant difference between the groups in terms of fatigue index ($p = 0.45$). In all four experimental groups — post-activation, caffeine, caffeine + post-activation, and placebo + post-activation —the average power increased significantly compared to the placebo group ($p = 0.001$). A comparison between intervention groups revealed that the average power increase in the caffeine + post-activation group was greater than in the other groups ($p = 0.001$). Furthermore, the peak power in the caffeine + post-activation group was more than in the other groups, and no significant difference was observed between the other experimental

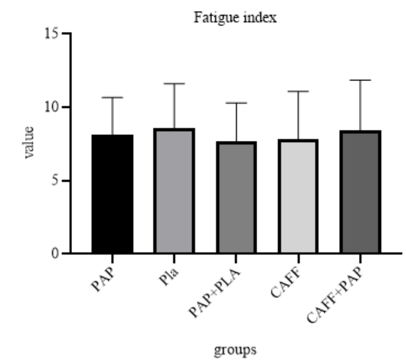


**Figure 1** The fatigue index value for different groups (post-activation/placebo/placebo with post-activation/caffeine/caffeine with post-activation)

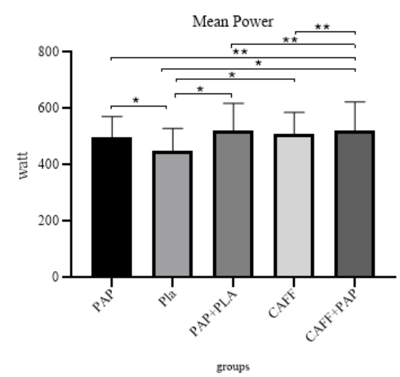


**Figure 2** Average power values for different groups (post-activation/placebo/placebo with post-activation/caffeine/caffeine with post-activation)

*Significant difference with the placebo group, **Significant difference with other groups

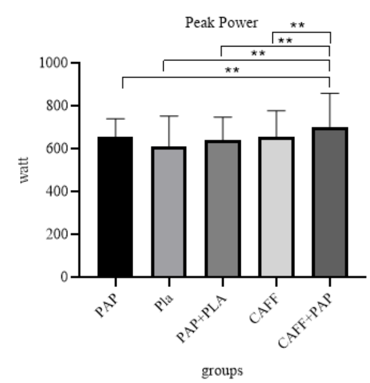


**Figure 3** Peak power value for different groups (post-activation/placebo/placebo with post-activation/caffeine/caffeine with post-activation)

*Significant difference with the placebo group

**Table 1** The mean and standard deviation of dependent variables and Repeated measures ANOVA

| Group | Fatigue Index | Mean Power | Peak power | Total time |
|---|---|---|---|---|
| PAP | 8.16 ± 1.51 | 496.75 ± 58.06 | 655.28 ± 86.91 | 34.2 ± 2.41 |
| Placebo | 8.56 ± 4.06 | 448.80 ± 67.46 | 610.22 ± 144.06 | 35.40 ± 2.71 |
| Placebo + PAP | 7.67 ± 2.64 | 521.97 ± 36.25 | 640.89 ± 108.55 | 33.54 ± 2.35 |
| Caffeine | 7.81 ± 3.27 | 509.76 ± 43.96 | 658.73 ± 119.96 | 33.7 ± 2.18 |
| Caffeine + PAP | 8.40 ± 4.45 | 535.81 ± 96.99 | 704.25 ± 156.23 | 32.20 ± 1.77 |
| Sig | 0.45 | 0.001* | 0.001* | 0.001* |
| Effect size | 0.007 | 0.39 | 0.51 | 0.28 |

*: Between-group significant difference

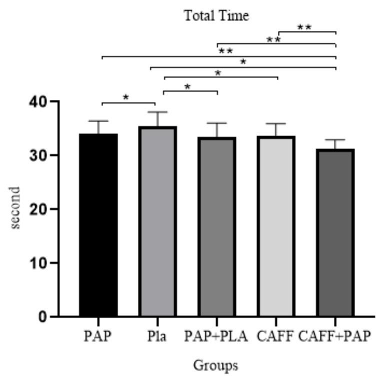


**Figure 4** Anaerobic capacity value for different groups (post-activation/placebo/placebo with post-activation/caffeine/caffeine with post-activation)

*Significant difference with the placebo group, **Significant difference with other groups

groups.

The total time decreased significantly compared to the placebo group in all other groups (p = 0.001). A comparison between intervention groups showed that the total time decreased in the caffeine + post-activation group more than other groups. The effect is shown in Table 1. As can be seen, the largest effect size was observed for peak power, at 51%, while the average power, total time, and fatigue index showed changes of 39%, 28%, and 0.7%, respectively.

## 4 Discussion

Regarding the average power and peak power, it was observed that the caffeine + PAP method resulted in a greater increase in average power compared to other methods. However, a comparison between the groups demonstrated that a combination of supplementation and PAP methods could dramatically increase the average power of Wushu athletes. On the ergogenic effects of caffeine ingestion, the present findings are consistent with the research results of Graham et al., Varmazyar et al., and Grgic on aerobic and anaerobic performance.[15-17] It was concluded that acute caffeine supplementation can increase explosive power and peak power in the Wingate anaerobic test.[16] Caffeine ingestion has an ergogenic effect on anaerobic power through different mechanisms.[18] caffeine supplementation stimulates the central nervous system (CNS) through the adenosine receptor antagonist. Caffeine can interfere with the increase in adenosine and prevent pain. On the other hand, it increases the release of adrenaline (epinephrine), the breakdown of glycogen, and glucose consumption. It has been noted that caffeine supplementation may delay the onset of lactate threshold, which is directly correlated with enhanced power output. It has also been suggested that caffeine can lead to positive changes in facilitating muscle contraction by altering the expression of genes encoding sodium, potassium, and calcium pumps.[19]

On the other hand, PAP can change neuromuscular performance and consequently power output and RAST execution time through other mechanisms.[20,21] Asencio et al. explored the effect of a squat warm-up on handball players and concluded that PAP improved performance.[22] Unlike caffeine, PAP increases performance probably more through intramuscular changes. One proposed mechanism is the phosphorylation of myosin regulatory light chains via myosin light chain kinase (MLCK), which theoretically renders actin-myosin interaction more sensitive to $Ca^{2+}$ released from the SR.[19]

According to MVC-induced twitch potentiation (TP), twitch amplitude is dependent on the intensity and duration of voluntary effort and muscle fiber type in voluntary contraction. Research conducted on human tibialis anterior (TA) and plantarflexor (PF) muscles showed that a < 75% contraction did not activate the maximal isometric strength of the TP, while an intensity lasting approximately 10 seconds could cause the greatest TP. Consequently, in the context of PAP, it is recommended to maintain an intensity exceeding 80% for a duration of at least 10 seconds. It was also noted that TP is larger in type-II fibers, i.e., fast-twitch fibers, due to their higher responsiveness to myosin regulatory light chain (RLC) phosphorylation in response to previous contraction.[23] Although the effect of TP on human motor performance is uncertain, all the evidence suggests that strength-power performance increases after TP. TP can probably increase peak velocity and power in dynamic voluntary contractions by increasing the speed of force development and acceleration. Therefore, post-activation probably affects motor performance and improves the performance and record of sprint and strength athletes. [16] In this research, the fatigue index exhibited minimal variation, even with enhancements in anaerobic power and mechanical output. It was anticipated that fatigue would escalate with increased workload; however, it is plausible that caffeine and PAP mitigated fatigue via distinct mechanisms. Another hypothesis is that caffeine may delay the perceived fatigue without affecting mechanical fatigue during short intervals.

To date, no research has examined the simultaneous effect of supplement intake and its interaction with PAP. The present study was the first one that examined the effect of the combination of two interventions on the performance of Wushu athletes. The results suggested that the combination of the two methods caused a significant increase in power output compared to the individual application of each intervention. This was probably because each intervention could improve performance through its own pathways, and combining the two interventions doubled this improvement. These findings are practical for coaches and professional athletes seeking to achieve better results, as they can provide a more effective warm-up before a competition by applying the PAP method, supplemented with caffeine, and can also enhance muscle contractility and delay fatigue. These results can be applied in martial arts with a similar time to RAST and are highly dependent on anaerobic power. Improved explosive power and performance likely lead to an improvement in technique execution during competition, and subsequently, performance. This study has some limitations that should be considered when interpreting the results, including a small sample size, a lack of female participants, the absence of blood or hormonal markers (e.g., lactate), and the lack of long-term follow-up.

## 5 Conclusion

As reported, the results obtained in the present study demonstrated that caffeine ingestion along with PAP can have a more significant effect on improving the anaerobic performance of Wushu athletes in RAST. Since Wushu is a sport in which the contribution of energy regeneration in the competition is mainly anaerobic and similar to RAST, it is preferable to apply this process in the preparation of athletes, and even before the competition. Coaches and athletes may also benefit from research findings regarding the utilization of PAP (70% 1RM) and caffeine (with a 6 mg/kg body mass dosage). This suggestion is made with caution because there is a need for extensive future research in this area.

## Declarations

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**Artificial Intelligence Disclosure**
The authors confirm that no artificial intelligence (AI) tools were used in the preparation of this manuscript.

**Authors' Contributions**
All authors have approved the final manuscript. Amir Hossein Delshad served as the supervisor, reviewer, and editor of the article. Morteza Khodabande Lou conducted the investigation and data curation. Naser Heydari was responsible for data analysis, drafting the original manuscript, and overseeing project administration, including submission and revisions.

**Availability of Data and Materials**
The data supporting the findings of this research can be obtained from the corresponding author upon a reasonable request.

**Conflict of Interest**
The authors declare that they have no conflict of interest regarding the publication of this article.

**Consent for Publication**
Not applicable.

**Ethical Considerations**
Before conducting this study, written informed consent was acquired from all professional athletes before participation, and data anonymity was strictly maintained. This study was approved under the Code of Ethics 70918765.

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