International Journal of Strength and Conditioning

Esmaelzadeh Toloee, M., Malekshahi, O., Mohammadzadeh, H., & Romano, V. (2026). Caffeine Mouthwash and Its Impact on Anaerobic Power in Active Men. International Journal of Strength and Conditioning
https://doi.org/10.47206/ijsc.v6i1.596

Caffeine Mouthwash and Its Impact on Anaerobic Power in Active Men

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ABSTRACT

Caffeine is considered one of the most commonly used ergogenic aids across a wide range of athletic disciplines. Its popularity has led to the development of various forms, including caffeine mouthwashes. Caffeine mouthwashes, as one of the newer delivery methods, have attracted researchers' attention due to their direct and rapid absorption through the oral mucosa. The present study aimed to investigate the effects of varying caffeine mouth rinse protocols on Wingate test anaerobic power indices. Using a randomized crossover design, participants completed four experimental sessions in which they used a 2% caffeine mouthwash for 10, 20, or 30 seconds, or a placebo mouthwash, before performing a Wingate anaerobic test. During each session, following the mouthwash administration, anaerobic power indices were assessed using the Wingate test on a cycle ergometer. All data were analyzed through repeated-measures ANOVA. Significance was set at $p < 0.05$. Data analysis showed that caffeine mouthwash duration had no significant effect on power drop ($p = 0.165$) or mean anaerobic power ($p = 0.962$). In contrast, peak anaerobic power was significantly higher following the 30 second caffeine mouthwash compared with placebo ($p = 0.033$), and time to reach maximum speed was significantly shorter after the 30 second condition compared with both the 10 second caffeine mouthwash and placebo ($p < 0.05$). Shorter rinsing durations (10 and 20 seconds) did not differ from placebo for these outcomes. These findings indicate that caffeine mouthwash can influence select anaerobic performance indices, with ergogenic effects evident only when rinsing duration is sufficiently prolonged.

Keywords: Peak power, Performance enhancement, Sport nutrition, Wingate test.

INTRODUCTION

Caffeine, as one of the most widely consumed alkaloid-based supplement, has long held a prominent place among athletes and the general public. It is extensively found in many foods and beverages, including tea, coffee, soft drinks, and energy drinks (4,13). Research indicates that over 90% of the U.S. population regularly consumes approximately 210–238 mg/person/day of caffeine, whereas the world average caffeine consumption is 76 mg/person/day (6,13). From a pharmacological perspective, caffeine is rapidly absorbed after ingestion, reaching peak blood concentration within 90 to 100 minutes, and remains elevated for approximately 3 to 4 hours before gradually declining (14,20). This absorption and metabolism profile underpins caffeine's widespread effects on various bodily systems, including the central nervous, hormonal, muscular, and metabolic systems (14,22,33,35). Specifically, the primary mechanism of caffeine's action is the blockade of adenosine receptors, leading to increased release of excitatory neurotransmitters such as dopamine and glutamate. This enhances alertness, concentration, and reduces the perception of fatigue (38).

Beyond its direct effects on the nervous system, caffeine also plays a significant role in enhancing metabolic processes, notably by increasing fat oxidation and increasing metabolism. Recent studies have shown that caffeine consumption boosts lipolysis and raises the levels of free fatty acids in the bloodstream, processes that contribute to improved endurance performance and greater exercise tolerance (1,12). Furthermore, research suggests that caffeine positively influences energy regulation and physiological efficiency by enhancing insulin sensitivity and glucose metabolism (43).

A variety of caffeine delivery forms are available on the market. These include liquid forms such as tea, coffee, soft drinks, and energy drinks (32); solid forms like chocolate products (36); and newer forms such as inhalable sprays (41), caffeine mouthwashes (28), caffeine gels (40), and caffeine gums (23). Each form, depending on its formulation, dosage, and absorption method, exhibits varying effects on physiological indices and athletic performance. Caffeine mouthwashes, as one of the newer delivery methods, have attracted researchers' attention due to their direct and rapid absorption through the oral mucosa. Although studies have indicated that caffeine mouthwash may not significantly affect endurance performance (11,34,41), existing evidence suggests it could play a role in enhancing anaerobic performance and high-intensity sprint activities (2,27).

Nevertheless, the effectiveness of caffeine mouthwashes appears to depend on both solution concentration and mucosal contact time, as the present protocol used a 2% caffeine solution rinsed for 10, 20, or 30 seconds, with performance improvements observed only following the longest rinsing duration (28). Increased concentration and extended rinsing times may result in better absorption and stronger effects (41). Given the established role of caffeine in sport performance and the wide variation in outcomes reported in caffeine mouthwash studies, this study focused on two methodological factors that have likely contributed to inconsistent findings, 1) the solution concentration and 2) oral exposure time. Previous work has frequently used short rinsing durations or lower caffeine concentrations, approaches that have often failed to affect anaerobic performance measures (28). In contrast, evidence suggests that greater oral exposure and higher concentrations may enhance sensory stimulation and neural signaling related to performance regulation (41). Accordingly, the present study employed a 2% caffeine solution with rinsing durations of 10, 20, and 30 seconds to examine whether extended oral contact would differentially influence anaerobic power indices.

Specifically, we examined whether different rinse durations influenced peak power, mean power, power drop, and time to maximum speed. By relying on the latest scientific data and previous research, this study seeks to provide a better understand the absorption processes and diverse physiological effects of caffeine, thereby offering insights to optimize caffeine supplementation strategies among athletes.

METHODS

Experimental Approach to the Problem

This study employed a controlled trial, within-subjects experimental design in which ten trained male participants completed four separate test protocols, each involving a different caffeine mouth rinse condition, to evaluate the effects on anaerobic performance. Each participant attended five separate sessions. The first session was dedicated to orientation and familiarization. At each session, participants arrived at a predetermined time and rested for at least 30 minutes upon entering the laboratory to stabilize heart rate and acclimatize to the environmental conditions. Heart rate was continuously monitored using a smart wristband using a Mi Band 4. Ambient temperature was measured, and heating or cooling devices were used to maintain consistent conditions.

Before starting each protocol, participants' body weight was measured. Then, participants performed a standardized five-minute dynamic warm-up. Following the warm-up and upon expressing readiness, participants used the caffeine mouth rinse according to the assigned protocol. One minute after rinsing, they performed a Wingate anaerobic cycling test using a Monark 894E cycle ergometer. The use of different caffeine mouth rinse protocols was randomly assigned. A two-day recovery period was scheduled between each test session.

Participants

Ten healthy and trained male subjects (mean age: 22.5 ± 3.8 years; height: 176 ± 9cm; weight: 78 ± 13kg) volunteered to participate in this study, and all participants completed the study protocols with no dropouts or exclusions after enrollment. Although the sample size was modest (n=10), it was consistent with prior exploratory studies in this field (25,28). Daily caffeine intake was assessed using the using the Caffeine Consumption Questionnaire (21). Participants consuming more than 300 mg of caffeine per day were excluded from the study. This study was approved by an Institutional Review Board (IRB) and subjects were informed of the benefits and risks of the investigation prior to signing an institutionally approved informed consent document to participate in the study.

Procedures

Caffeine mouth rinses were prepared by dissolving ten 200 mg caffeine tablets (a total of 2 g of caffeine) in 100 mL of distilled water to create a 2% caffeine solution (41). The resulting solution was divided into 25 mL portions in disposable cups for participant use. The rinsing duration was timed using a stopwatch. During the one-minute interval after rinsing, the Wingate ergometer was prepared for testing using a Monark 894E cycle ergometer.

- *Protocol 1 (Session 2):* Participants rinsed with 25 mL of a 2% caffeine solution for 10 seconds. One minute later, they performed the Wingate test.
- *Protocol 2 (Session 3):* Participants rinsed with 25 mL of a 2% caffeine solution for 20 seconds, followed by the Wingate test after one minute.
- *Protocol 3 (Session 4):* Participants rinsed with 25 mL of a 2% caffeine solution for 30 seconds. One minute later, they performed the Wingate test.
- *Protocol 4 (Session 5):* Participants rinsed with 25 mL of a placebo solution containing decaffeinated for 30 seconds. After one minute, the Wingate test was conducted.

Statistical Analysis

Statistical analyses were conducted using SPSS version 22 (IBM Corp., Armonk, NY, USA). Normality of all dependent variables was assessed using the Shapiro–Wilk test. All outcome variables (peak anaerobic power, mean anaerobic power, power drop, and time to reach maximum speed) were compared across the four caffeine mouth rinse protocols using one-way repeated-measures ANOVA. When significant differences were identified, Bonferroni-adjusted post hoc tests were used for pairwise comparisons. Statistical significance was set at $p < 0.05$, with 95% confidence intervals (CIs) were reported where appropriate.

RESULTS

Power Drop

Change difference in the four protocols were analysed using repeated-measures analysis of variance. No significant effect of the protocols on the Power Drop was observed ($p = 0.165$). Additionally, pairwise comparisons using the Bonferroni test revealed no significant differences in the power drop among the four protocols (Figure 1A).

Peak Anaerobic Power

Changes in peak anaerobic power across the four protocols were analyzed using repeated-measures analysis of variance, and a significant effect was observed among the protocols ($p = 0.044$). Furthermore, pairwise comparisons using the Bonferroni test revealed a significant difference between the third protocol (30 seconds of caffeine mouth rinse) (235 ± 73) and placebo ($p = 0.033$) (Figure 1B).

Mean Anaerobic Power

Changes in mean anaerobic power at the end of the four protocols were analysed using repeated-measures analysis of variance, and no significant effect was observed among the protocols ($p = 0.962$). No significant differences in mean anaerobic power were found among the four protocols (Figure 1C).

Time to Reach Maximum Speed

Changes in the time to reach maximum speed at the end of the four protocols were analyzed using repeated-measures analysis of variance), and significant differences were observed among the protocols ($p = 0.013$). Pairwise comparisons revealed significant differences between Protocol 3 (30 seconds caffeine mouthwash) (±0.24) and Protocol 1 (10 seconds caffeine mouthwash) ($p = 0.028$). Additionally, significant differences in time to reach maximum speed were observed between Protocol 3 (30 seconds caffeine mouthwash) (±0.25) and the placebo protocol ($p = 0.04$) (Figure 1D).

DISCUSSION

The findings of this study indicate that caffeine mouthwash protocol may have a positive effect on certain anaerobic power indices (peak anaerobic

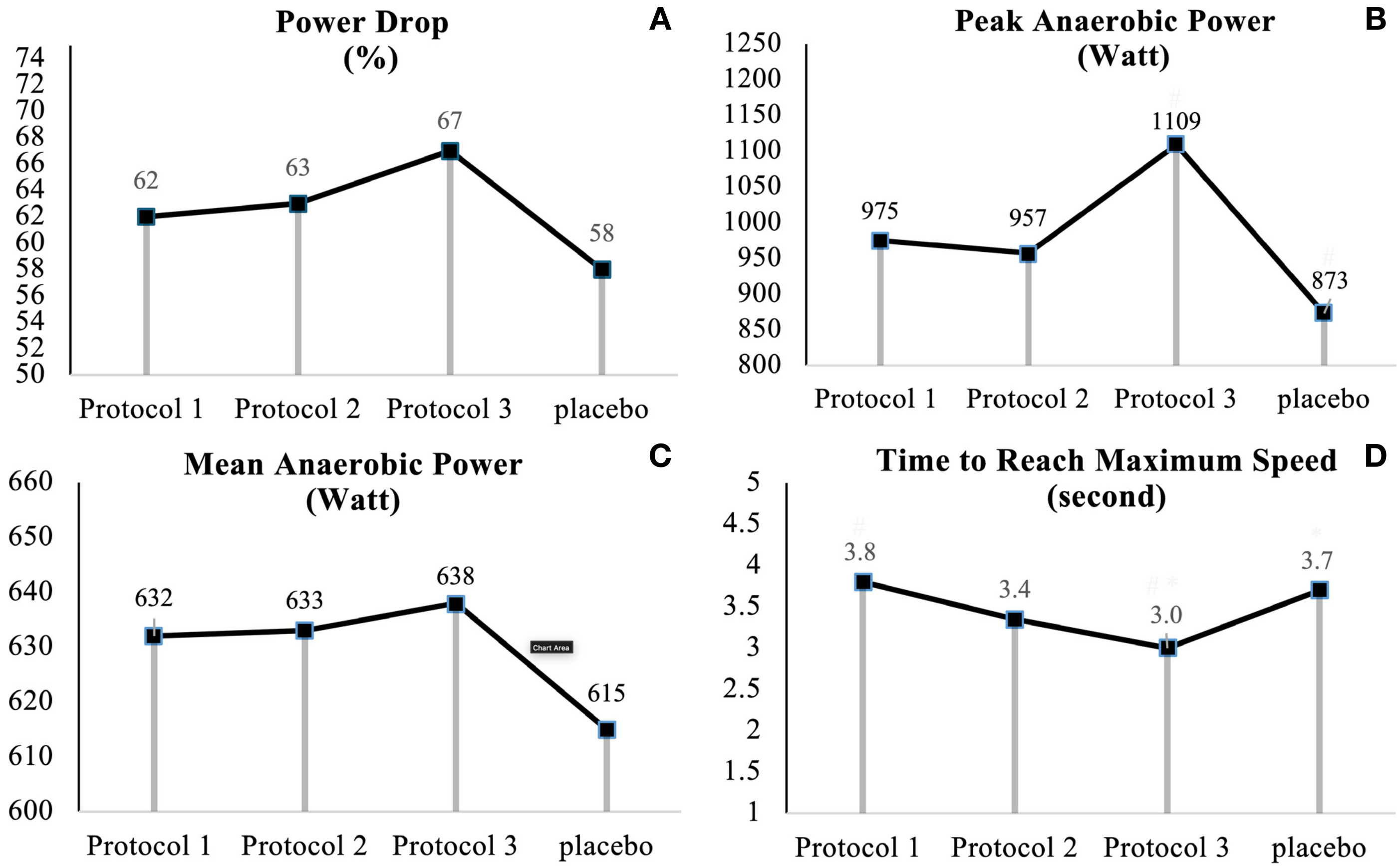

Figure 1. Comparison of Wingate test performance indexes following 25 mL of a 2% caffeine solution mouthwash for 10 (protocol 1), 20 (protocol 2), 30 seconds (protocol 3), and placebo groups. #Indicates significant difference among pairs ($p < 0.05$). *Indicates significant difference among pairs ($p < 0.05$)

power and time to reach maximum speed), and it seems that this positive effect is largely dependent on the duration of the caffeine mouthwash. These results add to current literature that examines the effect of caffeine on anaerobic power, and the results have been quite inconsistent across studies (9,17). Kang and colleagues examined the effects of 0.5 and 2.5 mg caffeine per kilogram of body weight in both trained and untrained individuals. results showed that caffeine improved all three indices of peak anaerobic power, average anaerobic power, and total anaerobic power in both groups, and the dose of caffeine did not affect performance (24). On the other hand, many studies have shown that caffeine consumption has no effect on anaerobic performance (3,7,18). The combined effect of caffeine and carbohydrate supplements on anaerobic power has also been investigated the but found no significant effect (26).

Caffeine works in the central nervous system by binding to adenosine receptors and increasing the intracellular concentration of cyclic adenosine monophosphate (AMP). This action in the central nervous system increases alertness and concentration, reduces fatigue, and leads to greater recruitment of motor units (30). The mechanisms described above occur when caffeine is consumed orally and increases blood caffeine levels. However, in our study, caffeine was used as a mouthwash, and the time between using the mouthwash and the Wingate test was not sufficient to significantly elevate blood caffeine concentration (40). Recent studies have shown that caffeine mouthwashes improved jump performance (25,39). Notably, studies on anaerobic indices such as time to reach peak power and time spent at peak power have not provided conclusive results; therefore, further research on the effect of caffeine consumption on these two indices is necessary.

Based on the findings of the present study, improvements in certain anaerobic indices may relate to sensory or neuromodulator pathways, such as bitter taste receptor activation. While speculative, these findings align with previous research indicating that oral stimulation can influence motor output (8,16). The effects of caffeine and carbohydrate mouthwashes are consistent with the present study (20). Although both caffeine and carbohydrate mouthwashes have been associated with performance improvements, these effects likely arise from distinct oral sensory pathways. Carbohydrate mouthwash effects are attributed to activation of carbohydrate-sensitive oral receptors rather than caffeine-related mechanisms (2).

Studies have been conducted on the mechanisms of caffeine mouthwashes, initially suggesting that caffeine inhibits adenosine receptors in the mouth, thereby preventing adenosine activity (5). This interaction would increase the permeability of the buccal mucosa, allowing caffeine to be absorbed into the bloodstream (36). However, experimental studies have found this theory to be somewhat unlikely, as after the use of caffeine mouthwashes, blood caffeine concentrations were measured, and no significant changes were found. This led to the rejection of the initial theory (10). The findings of the present study also somewhat refute this initial theory, as no changes in the fatigue index were observed. If caffeine were absorbed into the bloodstream, changes in the fatigue index should have been noticed.

Another proposed mechanism for the improvement in performance due to caffeine mouthwashes is related to taste receptors in the oral cavity. Specifically, bitter taste receptor cells located in the epithelial layer of the pharyngeal cavity are activated when caffeine is consumed (29). Studies have shown that these cells are activated when caffeine is consumed (31). Researchers believe that by activating these receptors, the bitter taste can activate neural pathways associated with taste, ultimately stimulating regions of the brain involved in processing and reward (such as the motor cortex), leading to performance improvement (15,42). This mechanism appears logical and aligns with the findings of the present study, as only the anaerobic power indices related to the nervous system showed improvement.

Several constraints must be considered when interpreting the results of this study. Blood caffeine concentrations were not measured, and therefore systemic absorption following the mouthwash protocol cannot be ruled out with complete certainty, even though prior investigations have consistently reported no meaningful elevations in circulating caffeine after mouth rinsing alone (10,28,41). In addition, the study did not include measures of neural activity, corticospinal excitability, or perceptual responses to the mouthwash. As a result, the proposed involvement of oral sensory and neuromodulatory pathways remains inferential and based on earlier work demonstrating links between oral stimulation, central activation, and motor output (15-17,42). Individual factors such as habitual caffeine use, genetic variability in bitter taste receptor expression, and training background were not controlled, all of which may influence responsiveness to caffeine and oral sensory stimuli (21,31,34). Anaerobic performance was evaluated using a single Wingate protocol, which limits extrapolation to other anaerobic or repeated sprint tasks, where findings related to caffeine mouth rinsing have been inconsistent (2,5,11,27). Finally, the study focused on acute responses only, and repeated exposure to caffeine mouthwash may produce different outcomes over time due to habituation or altered sensory signaling (41).

PRACTICAL APPLICATIONS

Based on the results of the present study, caffeine mouth rinsing does not appear to produce consistent improvements across all anaerobic performance variables. Instead, any potential benefits seem to be condition specific and limited to particular outcomes and protocols. In this study, a 30 second rinse with a 2% caffeine solution was associated with higher peak anaerobic power and a shorter time to reach maximum speed compared with placebo, whereas shorter rinsing durations (10 and 20 seconds) did not differ meaningfully from placebo. These findings are in line with previous research suggesting that the ergogenic effects of caffeine mouth rinsing are highly dependent on methodological factors, particularly caffeine concentration, oral exposure time, and the selected performance outcome (28,41). Studies employing brief rinsing durations or lower concentrations have frequently reported no effects on anaerobic or strength based performance (5,28), while investigations using prolonged or repeated rinsing protocols have observed improvements in select high intensity or neuromuscular outcomes (25,27,39).

From a practical standpoint, athletes and practitioners should interpret caffeine mouthwash strategies with caution. The available evidence indicates that any performance benefit is likely to be modest, task specific, and sensitive to protocol design, rather than reflective of a generalized enhancement in anaerobic performance (2,9,26). As such, caffeine mouth rinsing may be considered a situational aid under specific conditions, but it should not be expected to consistently improve all aspects of anaerobic power.

Therefore, the duration and concentration of caffeine mouth rinses appear to be critical methodological factors that influence performance outcomes. From a practical standpoint, athletes and practitioners should recognize that variations in protocols in the research, such as rinse time, solution strength, and timing relative to exercise, that may explain the inconsistencies in the literature and should be carefully considered when applying caffeine mouth rinse strategies. While these findings are promising, further research with larger samples and standardized protocols is required before firm recommendations can be made.

CONFLICTS OF INTEREST

The authors report no conflicts of interest.

FUNDING

There is no funding to disclose for this research study

ETHICAL APPROVAL

This study was approved by an Institutional Review Board (IRB) and subjects were informed of the benefits and risks of the investigation prior to signing an institutionally approved informed consent document to participate in the study.

DATES OF REFERENCE

Submission - 25/06/2025
Acceptance - 06/05/2026
Publication - 04/09/2026

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