THE EFFECTS OF GLUCOSE, CAFFEINE, AND COMBINED GLUCOSE-CAFFEINE SUPPLEMENTATION ON AEROBIC PERFORMANCE IN UNDERGRADUATE STUDENTS

Jialin YANG[1], Sukanya CHAROENWATTANA[2], Somporn SONGTRAKUL[2] and Kanok PANTHONG[3]

1 Master's Student, Faculty of Sports Science, Burapha University, Thailand; 65910132@go.buu.ac.th
2 Faculty of Sports Science, Burapha University, Thailand
3 Faculty of Education, Burapha University, Thailand

ABSTRACT

Objective: This study aimed to investigate the acute effects of glucose, caffeine, and glucose-caffeine combined mouthwash on specific physiological and sensory responses in college students during submaximal aerobic exercise. Methods: This single-blind randomized controlled trial enrolled 45 healthy male college students aged 18 to 22 years. Based on baseline fitness levels, participants were randomly assigned to three groups (n = 15 per group) using a serpentine allocation method: a 6% glucose group, a 10 mg caffeine (dissolved in 25 mL) group, and a glucose-caffeine combined mouthwash group. All participants underwent Åstrand-Rhyming submaximal aerobic dynamometer testing. Mean arterial pressure (MAP), heart rate (HR), estimated VO2, and subjective fatigue level (RPE) were measured before and after exercise. Paired-samples t-tests were used for intragroup comparisons. Results: All three mouthwashes significantly increased mean arterial pressure (MAP) and heart rate (HR) (all $p < .001$). No statistically significant change was observed in estimated oxygen uptake (VO2). Subjective perceived fatigue (RPE) responses differed under different conditions. No significant differences were found in any variables among the groups. Conclusion: The acute physiological responses induced by glucose, caffeine, and glucose-caffeine mixed mouthwashes were similar. Due to the lack of a placebo (water) control group, these variations cannot be attributed to specific mouthwashes. Future research should employ effective methods for measuring acute exercise performance and include a placebo control group.

Keywords: Mouthwash, Glucose, Caffeine, Enhancer, Submaximal Intensity Exercise, Aerobic Exercise Performance

CITATION INFORMATION: Yang, J., Charoenwattana, S., Songtrakul, S., & Panthong, K. (2026). The Effects of Glucose, Caffeine, and Combined Glucose-Caffeine Supplementation on Aerobic Performance in Undergraduate Students. *Procedia of Multidisciplinary Research, 4*(7), 46.

INTRODUCTION

Glucose and caffeine are widely studied energy enhancers. However, oral administration can cause gastrointestinal discomfort. Recent evidence suggests that rinsing with these substances alone can activate oral receptors (T1R2/T1R3 for carbohydrates; TAS2R for caffeine) and affect central nervous pathways in the absence of ingestion.

Therefore, mouthwash protocols are considered a practical alternative that minimizes systemic side effects. Previous studies have examined glucose and caffeine mouthwashes separately, but direct comparisons of the acute physiological responses to glucose, caffeine, and their combinations remain limited. Therefore, this study evaluated changes in mean arterial pressure (MAP), heart rate, estimated oxygen uptake, and subjective fatigue level (RPE) before and after exercise in healthy male university students following three mouthwash interventions.

RESEARCH METHODS

Ethical Approval

This study was approved by the Ethics Committee for Human Research at Burapha University (IRB3-019/2569; valid until March 10, 2027). All participants signed written informed consent forms in accordance with the Declaration of Helsinki.

Participants: Forty-five healthy male undergraduate students (aged 18-22 years) from the Faculty of Sports Science at Burapha University, Thailand, voluntarily participated in this study. Inclusion criteria required participants to have no cardiovascular or musculoskeletal diseases that could affect athletic performance and a daily caffeine intake ≤200 mg. Participants avoided caffeine intake and strenuous exercise for 24 hours prior to the test.

Study Design and Interventions: This study employed a single-blind, randomized controlled trial design. Participants were ranked based on baseline fitness levels and randomly assigned to one of three groups (n = 15) using a serpentine method:

- Group 1: 25 mL 6% glucose solution
- Group 2: 25 mL caffeine solution (10 mg)
- Group 3: 25 mL 6% glucose solution + 10 mg caffeine

All solutions were prepared by a licensed pharmacist on the day of testing. Participants first rinsed their mouths with 5 mL of saline, then rinsed with the designated solution for 5 seconds without swallowing. After a 5-minute rest, they underwent the Åstrand-Rhyming submaximal power cycling test (50 rpm, 6 minutes, target heart rate 120-170 bpm).

Outcome Indicators

- MAP: Electronic blood pressure monitor
- Estimated VO2 max: Åstrand-Rhyming nomogram (age corrected)
- Heart rate: Chest cuff monitor
- RPE: Borg 6-20 scale

All variables were recorded immediately before and after the 6-minute test.

Statistical Analysis

Data were analyzed using paired-samples t-tests. The significance level was set at $p < .05$. All p-values were reported as $p < .001$ where appropriate.

RESULTS

Table 1 Glucose Group (n = 15)

Variable	Pre-M (SD)	Post M (SD)	df	t	p
MAP	96.53(7.52)	116.80 (8.31)	14	14.21	<.001
VO2	37.34(4.68)	38.68 (5.12)	14	0.85	0.4
HR	69.93(6.65)	147.80 (14.24)	14	19.97	<.001
RPE	7.86 (2.26)	15.64 (2.63)	14	7.53	<.001

Table 2 Caffeine group (n = 15)

Variable	Pre-M (SD)	Post M (SD)	df	t	p
MAP	93.93 (7.08)	122.46 (8.67)	14	19.07	<.001
VO2	37.03 (4.63)	40.67 (5.45)	14	1.93	0.07
HR	78.66(15.43)	138.33(12.48)	14	26.31	<.001
RPE	7.46 (1.18)	13.93 (2.34)	14	5.93	<.001

Table 3 Combined glucose-caffeine group (n = 15)

Variable	Pre-M (SD)	Post M (SD)	df	t	p
MAP	93.46 (6.53)	122.26 (8.82)	14	16.83	<.001
VO2	37.10 (4.23)	38.35 (5.83)	14	0.74	0.46
HR	66.20 (8.80)	147.73 (14.18)	14	19.21	<.001
RPE	7.20 (1.01)	14.86 (2.85)	14	7.85	<.001

Within-group analyses showed significant increases in MAP and HR in all three conditions. Estimated VO2 did not change significantly. RPE increased significantly post-exercise in all groups, consistent with the expected perceptual response to submaximal exercise.

CONCLUSION AND DISCUSSION

The three mouth-rinse interventions produced comparable acute increases in MAP and HR, with no significant change in estimated VO2. The absence of a placebo (water) control group is acknowledged as a major limitation; therefore, the observed changes cannot be attributed solely to the glucose or caffeine content of the rinses. Future research should focus on valid acute performance measures (e.g., time-trial performance or power output) and include an appropriate placebo condition.

The lack of between-group differences suggests that, under the conditions tested, combining glucose and caffeine in a mouth rinse conferred no additional acute benefit over either substance alone. Practical implications and recommendations for future studies remain consistent with those previously outlined.

ACKNOWLEDGEMENTS

The authors thank Dr. Sukanya Charoenwattana (principal advisor) and Drs. Somporn Songtrakul and Kanok Panthong (co-advisors) for their guidance, as well as all participants and the staff of the Faculty of Sport Science, Burapha University.

REFERENCES

Åstrand, P. O., & Ryhming, I. (1954). *A nomogram for calculation of aerobic capacity (physical fitness) from pulse rate during submaximal work. Journal of Applied Physiology, 7(2), 218-221.* https://doi.org/10.1152/jappl.1954.7.2.218

Bottoms, L., Hurst, H., Scriven, A., Lynch, K., Bolton, J., Vercoe, L., & Sinclair, J. (2014). *The effect of caffeine mouth rinses on self-paced cycling performance. Comparative Exercise Physiology, 10(4), 239-245.* https://doi.org/10.1017/S1755254014000327

Carter, J. M., Jeukendrup, A. E., & Jones, D. A. (2004). *The effect of carbohydrate mouth rinse on 1-h cycle time trial performance. Medicine & Science in Sports & Exercise, 36(12), 2107-2111.* https://doi.org/10.1249/01.MSS.0000147589.52133.8F

Chambers, E. S., Bridge, M. W., & Jones, D. A. (2009). *Carbohydrate sensing in the human mouth: effects on exercise performance and brain activity. The Journal of Physiology, 587(8), 1779-1794.* https://doi.org/10.1113/jphysiol.2009.170016

Clarke, N. D., Kornilios, E., & Richardson, D. L. (2019). *Carbohydrate and caffeine mouth rinses do not affect maximum strength and muscular endurance performance. Journal of Strength and Conditioning Research, 33(3), 728-735.* https://doi.org/10.1519/JSC.0000000000001993

Coyle, E. F. (2004). *Fluid and fuel intake during exercise. Journal of Sports Sciences, 22(1), 39-55.* https://doi.org/10.1080/0264041031000164255

Devenney, S., Mangan, S., Shortall, M., & Collins, K. (2018*). Effects of carbohydrate mouth rinse and caffeine on high-intensity interval running in a fed state. Journal of Sports Sciences, 36(19), 2167-2174.* https://doi.org/10.1080/02640414.2017.1412345

Kerksick, C. M., Wilborn, C. D., Roberts, M. D., Smith-Ryan, A., Kleiner, S. M., Jäger, R., & Kreider, R. B. (2018*). ISSN exercise & sports nutrition review update: research & recommendations. Journal of the International Society of Sports Nutrition, 15(1), 38.* https://doi.org/10.1186/s12970-018-0242-y

Nehlig, A., Daval, J. L., & Debry, G. (1992). *Caffeine and the central nervous system: mechanisms of action, biochemical, metabolic and psychostimulant effects. Brain Research Reviews, 17(2), 139-170.* https://doi.org/10.1016/0165-0173(92)90012-B

Spriet, L. L. (2014). *Exercise and sport performance with low doses of caffeine. Sports Medicine, 44(Suppl 2), S175-S184*. https://doi.org/10.1007/s40279-014-0257-8

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Conflicts of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.



Copyright: © 2026 by the authors. This is a fully open-access article distributed under the terms of the Attribution-NonCommercial-NoDerivatives 4.0 International (CC BY-NC-ND 4.0).