The Effect of Coffee Consumption on VO2max and Heart Rate in Sports Science Students at Yogyakarta State University

Dampak Pemberian Minum Kopi Terhadap Vo2maks Dan Denyut Nadi Mahasiswa Ilmu Keolahragaan Universitas Negeri Yogyakarta

Original Article

Achmad Faishal Akbar*
Universitas Negeri Yogyakarta,
INDONESIA

Abstract.

Background Coffee is one of the most widely consumed beverages worldwide and is known for its caffeine content, which has been recognized as a legal ergogenic aid capable of influencing physical performance and cardiovascular responses. Although numerous studies have examined caffeine supplementation, limited evidence exists regarding the effects of coffee consumption as a natural caffeine source on aerobic capacity and heart rate responses, particularly in physically active populations.

Objectives This study aimed to examine the effects of coffee consumption on maximal oxygen uptake (VO_2max) and heart rate responses during and after aerobic exercise among sports science students.

Methods A quasi-experimental study with a repeated-measures design was conducted involving 25 physically active sports science students. Participants completed two conditions: a control condition without coffee consumption and an experimental condition with coffee consumption, separated by a 48-hour washout period. VO_2max was estimated using the Multistage Fitness Test, while heart rate was measured at rest, immediately after exercise, and during recovery. Data were analyzed using descriptive statistics and appropriate parametric or non-parametric tests with a significance level set at $p < 0.05$.

Results The results showed a significant increase in VO_2max following coffee consumption compared with the control condition ($p < 0.001$). Coffee intake also resulted in significantly higher resting and post-exercise heart rate values ($p < 0.001$). Furthermore, heart rate recovery at 10 and 15 minutes post-exercise was significantly faster in the coffee condition compared with the non-coffee condition ($p < 0.05$).

Conclusion Coffee consumption significantly improves aerobic capacity and modulates cardiovascular responses during and after exercise. These findings indicate that coffee, as a natural source of caffeine, may serve as an effective ergogenic aid for enhancing aerobic performance and cardiovascular recovery in physically active individuals.

Keywords: coffee consumption, caffeine, vo_2max, heart rate, aerobic performance, ergogenic aid

Received: November 28, 2025. Accepted: December 26, 2025
*Correspondence: faizalac1410@gmail.com
Achmad Faishal Akbar
Universitas Negeri Yogyakarta, Indonesia

INTRODUCTION

Coffee is one of the most widely consumed beverages worldwide and represents a major agricultural commodity with significant economic and cultural value. Indonesia is among the world's largest coffee-producing countries, supported by favorable tropical climate and diverse geographical conditions that enable the cultivation of various coffee species, particularly Arabica and Robusta [1][2]. Robusta coffee dominates Indonesian production due to its higher adaptability and resistance to pests, accounting for more than 80% of national output [3]. Beyond its economic importance, coffee consumption has become deeply embedded in daily lifestyles, extending from domestic settings to public spaces such as workplaces, sports facilities, and fitness centers [4]. This widespread consumption has raised increasing interest in understanding coffee's physiological and functional effects on the human body.

The popularity of coffee is closely related to its primary bioactive compound, caffeine, which exerts significant physiological effects on the central nervous and cardiovascular systems. Caffeine is a naturally occurring methylxanthine alkaloid found in coffee beans, tea leaves, and cocoa, and is known

for its psychoactive and stimulatory properties [5][6]. Previous studies have demonstrated that caffeine acts mainly by antagonizing adenosine receptors, leading to increased catecholamine release, elevated heart rate, enhanced alertness, and improved neuromuscular function [7][8]. Due to these mechanisms, caffeine has been widely recognized as an ergogenic aid capable of enhancing physical and cognitive performance, particularly during exercise.

In the context of sports and physical activity, caffeine is classified as a legal ergogenic substance and is no longer included in the list of prohibited substances by the World Anti-Doping Agency (WADA) [9]. Empirical evidence indicates that caffeine supplementation, typically at doses of 3–6 mg/kg body weight, can improve endurance performance, delay fatigue, and enhance muscle contractility by increasing calcium availability within muscle fibers and promoting greater fat oxidation [10][11]. These effects make caffeine, including that derived naturally from coffee, an attractive and accessible performance-enhancing strategy for athletes and physically active individuals.

Cardiorespiratory endurance is a fundamental component of health-related fitness and is commonly assessed through maximal oxygen uptake (VO_2max). VO_2max reflects the body's capacity to uptake, transport, and utilize oxygen during maximal exercise and is strongly associated with cardiovascular health and physical performance [12][13]. High-intensity or prolonged aerobic activities lead to acute physiological responses, including increases in heart rate, oxygen consumption, and body temperature, as part of normal cardiovascular adaptation to exercise stress [14]. Given caffeine's stimulatory effects on the cardiovascular system, its consumption prior to exercise may influence VO_2max outcomes as well as heart rate responses during and after physical activity.

Despite substantial evidence supporting the ergogenic effects of caffeine on anaerobic performance and short-duration high-intensity activities, findings related to aerobic capacity and cardiovascular responses remain inconsistent. Several studies have focused on isolated caffeine supplementation or laboratory-based endurance protocols, while fewer investigations have examined coffee as a natural caffeine source and its acute effects on aerobic performance indicators such as VO_2max and heart rate dynamics [15][16]. Moreover, individual variability in habitual coffee consumption may modulate cardiovascular responses, leading to differences in heart rate and blood pressure reactions following caffeine intake [17].

In Indonesia, research examining the physiological effects of coffee consumption in physically active populations remains limited, particularly in relation to aerobic fitness and cardiovascular responses. Most available studies emphasize general health outcomes or anaerobic performance measures, leaving a gap in understanding how coffee intake affects VO_2max and heart rate responses during aerobic exercise. This gap is especially relevant for sports science students and practitioners who regularly engage in physical activity and may consume coffee prior to training or testing sessions.

Therefore, this study aims to investigate the effects of coffee consumption on VO_2max and heart rate responses among students of Sports Science at Yogyakarta State University. By examining coffee as a natural ergogenic aid within an applied exercise context, this research seeks to provide empirical evidence regarding its influence on aerobic capacity and cardiovascular responses. The findings are expected to contribute to the scientific understanding of caffeine-based ergogenic strategies, inform evidence-based recommendations for coffee consumption before physical activity, and serve as a reference for future studies in sports physiology and performance optimization.

METHOD

Study Design

This study employed a quasi-experimental design using a repeated-measures approach to examine the effects of coffee consumption on aerobic performance and heart rate responses. Each participant completed two experimental conditions: a control condition without coffee consumption and an experimental condition with coffee consumption. The two sessions were separated by a 48-hour washout period to minimize residual effects of caffeine.

Participants

The participants were 25 undergraduate students from the Sports Science Program, Faculty of Sport Sciences and Health, Yogyakarta State University. Participants were selected using purposive sampling based on the following inclusion criteria: (1) enrollment as a sports science student, (2) aged over 18 years, (3) physically active, (4) previous experience consuming coffee, (5) no history of gastric

disorders or cardiovascular disease, and (6) willingness to participate voluntarily. All participants provided informed consent prior to data collection.

Experimental Procedures

Data collection was conducted over two sessions at the parking area of the Yogyakarta State University Sports Hall. All testing sessions were performed at the same time of day to control for circadian variation. In the control condition, resting heart rate was measured first, followed by heart rate measurements at 5, 15, and 30 minutes after the initial measurement. Participants then completed a Multistage Fitness Test (bleep test) to estimate VO_2max. Heart rate was recorded immediately after the test and during recovery at 10 and 15 minutes post-exercise.

In the experimental condition, participants followed the same procedures as in the control session, with the exception that coffee was consumed after the initial resting heart rate measurement. All subsequent measurements and testing procedures were conducted identically to the control condition.

Coffee Intervention

The intervention consisted of coffee consumption administered prior to aerobic testing. Coffee was provided after the first resting heart rate measurement in the experimental session. The use of coffee as a natural caffeine source was intended to reflect habitual consumption patterns among physically active individuals. Participants were instructed to consume the coffee entirely before proceeding to subsequent heart rate measurements and aerobic testing.

Measurements

Heart rate was measured manually using the palpation technique with the aid of a stopwatch. Measurements were taken at rest, during the pre-exercise phase, immediately after the bleep test, and during the recovery phase. Aerobic capacity was assessed using the Multistage Fitness Test, a widely used field-based test to estimate maximal oxygen uptake (VO_2max). VO_2max values were derived from test performance levels using standardized conversion tables.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 25. Descriptive statistics were calculated and presented as mean and standard deviation. The Shapiro–Wilk test was used to assess data normality, while variance homogeneity was evaluated using Levene's test. Differences between the control and coffee conditions were analyzed using an independent samples t-test for normally distributed data or the Wilcoxon signed-rank test for non-normally distributed data. Statistical significance was set at $p < 0.05$.

RESULTS AND DISCUSSION

Results

Participant Characteristics

A total of 25 sports science students participated in this study. All participants completed both experimental conditions (control and coffee consumption) without any adverse events. Baseline characteristics indicated that participants were physically active and met the inclusion criteria for aerobic fitness testing.

Data Distribution

Normality testing using the Shapiro–Wilk test revealed that several outcome variables were not normally distributed ($p < 0.05$). Homogeneity of variance testing showed acceptable variance distribution between conditions. Therefore, parametric or non-parametric statistical analyses were applied accordingly.

Effect of Coffee Consumption on VO_2max

Analysis of VO_2max values obtained from the Multistage Fitness Test demonstrated a significant difference between conditions. VO_2max was significantly higher following coffee consumption

compared with the control condition (Asymp. Sig. (2-tailed) = 0.000; $p < 0.05$). This finding indicates an improvement in aerobic capacity after coffee intake.

Table 1. Summary of Wilcoxon Sign Test Results

Tested Variables	Asymp. Sig. (2-tailed)	Description
VO2maks	0.000	Significant

Effect of Coffee Consumption on Resting Heart Rate

Resting heart rate measurements showed significant differences between the control and coffee conditions. Heart rate measured at 5, 15, and 30 minutes after the initial resting measurement was significantly higher in the coffee condition compared with the control condition ($p < 0.001$ for all time points).

Table 2. Summary of Independent Sample t-test Resting Heart Rate

Heart Rate	N	Lavane Test	Mean Difference	Std. Error Difference	Sig (2-tailed)	Description
After 5 minutes	25	.465	-6.880	1.509	0.000	Significant
After 15 minutes	25	.206	-8.640	1.512	0.000	Significant
After 30 minutes	25	.168	-14.880	1.389	0.000	Significant

Table 3. Mean and Standard Deviation of Heart Rate

Time	Treatment	Mean ± Std. Deviation
5 minutes	Without Drinking Coffee	74.40 ± 5.774
	Drinking Coffee	81.28 ± 4.861
15 minutes	Without Drinking Coffee	75.68 ± 5.991
	Drinking Coffee	84.32 ± 4.607
30 minutes	Without Drinking Coffee	77.28 ± 5.504
	Drinking Coffee	92.16 ± 4.239

Effect of Coffee Consumption on Post-Exercise Heart Rate

Heart rate measured immediately after completion of the Multistage Fitness Test was significantly higher in the coffee condition compared with the control condition ($p < 0.001$), indicating an acute cardiovascular response following coffee consumption during maximal aerobic exercise.

Table 4. Independent t-test of Heart Rate Immediately After the Bleep Test

Heart Rate	N	Lavane Test	Mean Difference	Std. Error Difference	Sig (2-tailed)	Description
Immediately after the bleep test	25	.341	-15.200	1.672	0.000	Significant

Effect of Coffee Consumption on Heart Rate Recovery

Significant differences were also observed in heart rate recovery between conditions. Heart rate measured at 10 minutes post-exercise was significantly lower in the coffee condition compared with the control condition ($p < 0.001$). Similarly, heart rate measured at 15 minutes post-exercise showed a

significant difference between conditions (p = 0.006), indicating a faster recovery following coffee consumption.

Table 6. Independent t-test Recovery Heart Rate

Heart Rate	N	Lavane Test	Mean Difference	Std. Error Difference	Sig (2-tailed)	Description
10 minutes after the bleep test	25	.002	10.720	2.673	0.000	Significant
105minutes after the bleep test	25	.408	4.960	1.726	0.006	Significant

Discussion

The present study investigated the effects of coffee consumption on VO_2max and heart rate responses in physically active sports science students. The findings demonstrated that coffee intake significantly increased VO_2max and altered cardiovascular responses, including resting heart rate, exercise heart rate, and post-exercise recovery. These results support the hypothesis that coffee, as a natural source of caffeine, exerts ergogenic effects on aerobic performance and cardiovascular regulation during and after exercise.

The significant improvement in VO_2max following coffee consumption aligns with previous studies reporting caffeine's ability to enhance aerobic capacity and endurance performance. Caffeine has been shown to increase oxygen utilization efficiency by stimulating the central nervous system, reducing perceived exertion, and enhancing motor unit recruitment during exercise [10]. Additionally, caffeine promotes greater reliance on fat oxidation, thereby sparing muscle glycogen and allowing individuals to sustain higher exercise intensity for longer durations, which may contribute to improved VO_2max outcomes [18].

The observed increase in resting and peak exercise heart rate after coffee consumption is consistent with the known stimulatory effects of caffeine on the cardiovascular system. Caffeine acts as an adenosine receptor antagonist, leading to increased sympathetic nervous system activity and elevated catecholamine release, which in turn increases heart rate and myocardial contractility [19]. Similar findings have been reported by [20], who demonstrated that caffeine intake acutely elevates heart rate and blood pressure, particularly in individuals who are not habitual caffeine consumers. This physiological response may enhance cardiac output during exercise, thereby supporting higher oxygen delivery to working muscles.

Interestingly, despite the elevated heart rate during exercise, the present study found that coffee consumption was associated with a faster heart rate recovery during the post-exercise phase. This finding suggests that caffeine may not impair autonomic recovery as previously assumed, but instead may facilitate more efficient cardiovascular adaptation following maximal exertion. Faster heart rate recovery is often associated with improved parasympathetic reactivation and cardiovascular fitness [21]. The enhanced recovery observed in this study may reflect improved metabolic clearance and cardiovascular efficiency following exercise, although the exact mechanisms warrant further investigation.

Compared with previous research, this study contributes novel evidence by examining coffee consumption rather than isolated caffeine supplementation in an applied field-based setting. While many studies have focused on caffeine capsules or controlled laboratory protocols, fewer investigations have explored the ergogenic effects of coffee as a commonly consumed beverage in real-world exercise contexts [19]. Given that coffee contains additional bioactive compounds such as polyphenols, its physiological effects may differ from pure caffeine supplementation, potentially influencing cardiovascular and metabolic responses during exercise.

From a practical perspective, the findings suggest that moderate coffee consumption prior to aerobic exercise may enhance aerobic performance and support cardiovascular responsiveness among physically active individuals. This has important implications for sports science students, recreational athletes, and practitioners who frequently consume coffee before training or fitness testing. However, individual variability in caffeine sensitivity, habitual intake, and genetic factors may influence cardiovascular responses, highlighting the need for personalized recommendations.

Several limitations should be acknowledged. The study did not quantify the exact caffeine dose relative to body mass, which may affect the magnitude of physiological responses. Additionally, heart rate was measured manually, and biochemical markers such as blood lactate or catecholamine levels were not assessed. Future studies should incorporate controlled caffeine dosing, objective heart rate monitoring devices, and larger sample sizes to further elucidate the mechanisms underlying coffee's ergogenic effects on aerobic performance and cardiovascular recovery.

CONCLUSION

This study demonstrates that coffee consumption exerts a significant influence on aerobic performance and cardiovascular responses in physically active sports science students. The findings indicate that coffee intake is associated with improved VO_2max, elevated resting and exercise heart rate, and enhanced post-exercise heart rate recovery. These results support the role of coffee, as a natural source of caffeine, as an effective ergogenic aid in the context of aerobic exercise. From a scientific perspective, this research contributes to the growing body of evidence on caffeine-based ergogenic strategies by highlighting the physiological effects of coffee consumption rather than isolated caffeine supplementation. The use of a field-based aerobic fitness test further strengthens the practical relevance of the findings, particularly for individuals who routinely consume coffee prior to physical activity or fitness assessment. In practical terms, moderate coffee consumption before aerobic exercise may be considered as a feasible strategy to enhance aerobic capacity and cardiovascular responsiveness in physically active populations. However, individual differences in caffeine sensitivity and habitual intake should be taken into account when applying these findings in training or testing settings. Future research should incorporate controlled caffeine dosing relative to body mass, objective heart rate monitoring technologies, and larger sample sizes to clarify the underlying mechanisms and optimize evidence-based recommendations. Overall, the present study underscores the importance of understanding coffee's physiological effects within sports and exercise contexts and provides a foundation for further investigations in sports performance and exercise physiology.

ACKNOWLEDGMENT

With gratitude, the author would like to express his deepest gratitude to all those who have provided support and contributions in the process of completing this research. Special thanks go to previous researchers who have been the main source of literature and references in this study. The authors also appreciate any technical and moral assistance provided in the preparation of this systematic review article.

AUTHOR CONTRIBUTION STATEMENT

The writing of this article involved roles in devising the research concept and design, reviewing and analyzing relevant literature, and drafting the overall manuscript.

CONFLICT OF INTEREST AND FUNDING

There is no conflict of interest

REFERENCES

[1] H. Lire Wachamo, "Review on Health Benefit and Risk of Coffee Consumption," *Med. Aromat. Plants*, 2017. doi: 10.4172/2167-0412.1000301

[2] Z. Ungvari and S. K. Kunutsor, "Coffee consumption and cardiometabolic health: a comprehensive review of the evidence," *GeroScience*. 2024. doi: 10.1007/s11357-024-01262-5

[3] U. Hasdiana, "STATISTIK KOPI INDONESIA," *Anal. Biochem.*, 2020. doi: 10.1007/978-3-319-59379- 1%0A

[4] T. Ayang and M. Sugiat, "Analisis Pengaruh Customer Relationship Management Terhadap Loyalitas Pelanggan Trzy Coffee Bogor," *INOBIS J. Inov. Bisnis dan Manaj. Indones.*, 2022. doi:

10.31842/jurnalinobis.v6i1.256

[5] M. D. D. Putra and S. O. Lontoh, "Hubungan Tekanan Darah, Frekuensi Nadi dan Konsumsi Kopi dengan Fokus pada Mahasiswa Kedokteran Universitas Tarumanagara Angkatan 2021," *Malahayati Nurs. J.*, 2024. doi: 10.33024/mnj.v6i12.15821

[6] H. Yao, L. Li, X. Wang, and Z. Wang, "Association of caffeine intake with all-cause and cardiovascular mortality in diabetes and prediabetes," *Diabetol. Metab. Syndr.*, 2024. doi: 10.1186/s13098-024-01417-6

[7] E. Szuster, A. Pawlikowska, A. Mandera, and P. Kostrzewska, "Impact of coffee on human health," *J. Educ. Heal. Sport*, 2020. doi: 10.12775/jehs.2020.10.09.024

[8] A. V. Mattioli, "Cardiovascular health and coffee: Insights from a recent cohort study," *Nutrition, Metabolism and Cardiovascular Diseases*. 2025. doi: 10.1016/j.numecd.2025.104115

[9] T. S. Petersen, "Sport, Neuro-Doping and Ethics," *Neuroethics*, 2021. doi: 10.1007/s12152-021-09461-z

[10] K. Southward, K. J. Rutherfurd-Markwick, and A. Ali, "The Effect of Acute Caffeine Ingestion on Endurance Performance: A Systematic Review and Meta–Analysis," *Sports Medicine*. 2018. doi: 10.1007/s40279-018-0939-8

[11] N. S. Guest *et al.*, "International society of sports nutrition position stand: caffeine and exercise performance," *Journal of the International Society of Sports Nutrition*. 2021. doi: 10.1186/s12970-020-00383-4

[12] C. M. Strale, F. Giakoni-Ramírez, F. Pinochet, A. Godoy-Cumillaf, P. Fuentes-Merino, and D. Duclos-Bastías, "Physical Fitness, Physical Activity and Quality of Life in Chilean College Students," *Retos*, 2024. doi: 10.47197/retos.v56.104184

[13] M. F. Mendoza, R. M. Sulague, T. Posas-Mendoza, and C. J. Lavie, "Impact of Coffee Consumption on Cardiovascular Health," *Ochsner J.*, 2023. doi: 10.31486/toj.22.0073

[14] A. Sulaiman, A. P. Utomo, R. Apriliyanto, and J. Iskandar, "Sosialisasi Pentingnya Tes dan Pengukuran Kondisi Fisik Atlet bagi Pelatih Sepak Bola," *... Indones.*, 2022. https://jurnal.unmuhjember.ac.id/index.php/ABDI/article/view/8757

[15] E. O. Aluko, E. E. Effiong, T. H. Olatunbosun, and G. E. Bassey, "Acute Effect of Honey-sweetened Coffee on Blood Pressure, Heart Rate and Blood Glucose Level in Healthy Female Subjects," *Cardiovasc. Hematol. Disord. - Drug Targets*, 2025. doi: 10.2174/011871529X348787241217103918

[16] Z. Wang, B. Qiu, J. Gao, and J. Del Coso, "Effects of Caffeine Intake on Endurance Running Performance and Time to Exhaustion: A Systematic Review and Meta-Analysis," *Nutrients*. 2023. doi: 10.3390/nu15010148

[17] J. Simon *et al.*, "Association of daily coffee consumption with cardiovascular health – results from the UK Biobank," *Eur. Heart J.*, 2021. doi: 10.1093/eurheartj/ehab724.2416

[18] I. Jamil, H. Lucheng, S. Habib, M. Aurangzeb, E. M. Ahmed, and R. Jamil, "Performance evaluation of solar power plants for excess energy based on energy production," *Energy Reports*, 2023. doi: 10.1016/j.egyr.2022.12.081

[19] K. Nieber, "The Impact of Coffee on Health Author Pharmacokinetics and Mode of Action Bioactive Components in Coffee," *Planta Med*, 2017. doi: 10.1055/s-0043-115007

[20] O. Zacharopoulou *et al.*, "Acute effect of coffee consumption on blood pressure, QTc interval, and heart rate variability in people with type 2 diabetes," *Hellenic Journal of Cardiology*. 2022. doi: 10.1016/j.hjc.2022.06.003

[21] T. Sugihartono, Y. Yarmani, and A. Sutisyana, "Pengukuran dan Analisis Kondisi Fisik Berbasis Labor Kelas Olahraga," *J. Dharma Pendidik. dan Keolahragaan*, 2021. doi: 10.33369/dharmapendidikan.v1i1.16086