

Pre-Exercise Coffee Consumption Enhances Recovery but Not Endurance in Male Medical Students

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Abstract—The purpose of this study is to analyze the effect of coffee before exercise on endurance and recovery state in male medical students. Six students were involved and subjected to alternating conditions of coffee consumption and non-consumption, with a washout period of about one week between interventions. Subjects consumed pure, highly soluble Robusta black coffee 60 minutes before the 12-minute Cooper test. The recovery of heart rate in 1 and 3 minutes (HR_{recov1} , HR_{recov3}) was recorded, and the endurance was assessed from Cooper-test VO_2max . The results showed there was improvement in HR_{recov} ($p=0.005$; $p=0.031$), however the improvement in endurance was insignificant ($p=0.569$). In conclusion, caffeine consumption one hour before exercise can accelerate post-exercise heart rate recovery. However, it does not yet improve endurance, which requires longer-term adaptations involving the cardiorespiratory and musculoskeletal systems.

Keywords— Caffeine, Recovery, Endurance, Heart Rate, Running, Healthy Lifestyle.

I. INTRODUCTION

In today's modern era, university students, including medical students, often face tightly packed class schedules and high academic demands. The high intensity of studying and the need to remain productive amid a heavy academic workload require optimal physical and mental endurance. This condition highlights the importance of the body's ability to maintain energy (endurance) and accelerate recovery after physical activity or mental fatigue in order to sustain learning productivity [1].

To support endurance and the recovery process, the consumption of supplements has become a commonly used strategy. For example, caffeine is a known stimulant that can boost alertness, reduce weariness, and improve both physical and cognitive function [2]. Several studies have shown that caffeine can increase the body's ability to persist longer in physical and mental activities, thus supporting productivity amid busy schedules [3]. However, research on the effects of caffeine on endurance and recovery remains varied, and most previous studies have focused on professional athletes or examined other parameters such as cognitive reaction, alertness, or muscle strength [4]. This indicates a research gap regarding the effects of caffeine on the student population.

Caffeine produces an ergogenic effect by interfering with adenosine signalling in the central nervous system, which helps reduce the sensation of tiredness and maintain alertness during both mental and physical tasks. As a result, sympathetic activity increases and more epinephrine and norepinephrine are released, supporting greater blood delivery to the working muscles and making energy use more efficient [1], [5]. In addition, caffeine also plays a role in supporting recovery processes, including modulation of autonomic function and acceleration of post-activity heart rate recovery [6], [7].

Because there is still limited information on how caffeine affects endurance and recovery in university students, this study aims to find out whether caffeine consumption influences running endurance and post-exercise recovery in medical students at Universitas Airlangga.

II. METHODS

This was an experimental study with post-test only control group design with same subjects in both groups. Data collection was carried out after each session, immediately after subjects completed the test. This study had received ethical clearance from the Ethics Committee for Research, Faculty of Medicine, Universitas Airlangga, Surabaya (242/EC/FKUA/2025).

A. Subjects

The subjects in this study were students of the Faculty of Medicine, Universitas Airlangga, who met the inclusion and exclusion criteria. Inclusion criteria included male students aged 19–24 years, in good general health, and willing to sign the informed consent. Exclusion criteria included visible signs of illness and being a professional or trained athlete. A total of six participants were involved, and all subjects participated in both the control and treatment sessions.

B. Caffeine Administration

For the treatment condition, each subject consumed pure, highly soluble Robusta black coffee, dissolved in 300 cc of water, with a caffeine dose about 3 mg/kg per kilogram of body weight, one hour before performing the 12-minutes Cooper test. All participants were instructed to not consume any caffeine-containing beverages and avoid heavy physical activity 48

hours before each session to prevent fatigue and ensure consistent physical condition.

C. Endurance and Recovery Test

The 12-minutes Cooper test was used to evaluate endurance, requiring the subjects to run at full effort for 12 minutes. The distance achieved in meters was taken as the endurance outcome.

During the test, each subject wore a heart rate monitor (Polar H10) to continuously record heart rate data. After completing the run, the subjects stood or walked slowly while heart rate recovery was measured at 1 minute (HRrecov_1) and 3 minutes (HRrecov_3) after exercise. HRrecov_1 and HRrecov_3 represent the decrease in heart rate within 1- and 3-minutes post-exercise. These parameters were used to evaluate the recovery rate of the cardiovascular system after exercise.

III. RESULTS

A. Characteristics of Research Subjects

TABLE 1. Characteristics of Research Subjects

No	Variable	n	Mean ± SD
1	Body Weight (kg)	6	65,58 ± 9,17
2	Height (m)	6	172,33 ± 3,92
3	Systolic Blood Pressure (mmHg)	6	117,16 ± 5,74
4	Diastolic Blood Pressure (mmHg)	6	76,5 ± 1,76
5	Resting Heart (bpm)	6	69,16 ± 2,04
6	SpO2 (%)	6	98,16 ± 0,75

Measurements of several parameters were carried out before the physical exercise intervention on the study subjects. The results of the descriptive analysis and comparison tests of subject characteristics in each group are presented in Table 1.

B. Analysis of Endurance with and without Caffeine Consumption

TABLE 2. Analysis of Endurance with and without Caffeine Consumption

No	Variable	Session	Mean ± SD (mL/kg/min)	P-Value
1	Endurance (VO2max)	With caffeine	26,86 ± 6,04	0,569
		Without caffeine	26,16 ± 4,08	

The normality test showed that endurance values under both conditions (with and without caffeine) were normally distributed. The results of the paired sample t-test in Table 2. indicate that there was no significant difference in endurance between the conditions with and without caffeine consumption.

C. Analysis of Recovery with and without Caffeine Consumption

TABLE 3. Analysis of Recovery with and without Caffeine Consumption

No	Variable	Session	Mean ± SD	P-Value	
1	Recovery (HR; BPM)	HRrecov_1	With caffeine	-23,66 ± 9,79	0,005
			Without caffeine	-34,50 ± 7,28	
		HRrecov_3	With caffeine	-50,83 ± 8,79	0,031
			Without caffeine	-55,50 ± 9,83	

The normality test showed that HRrecov values in both

conditions (with and without caffeine) were normally distributed. The results of the paired sample t-test in Table 3. indicate that there was a significant difference in HRrecov between the conditions without caffeine and with caffeine consumption.

IV. DISCUSSIONS

A. The Effect of Caffeine on Endurance

The results of this study showed that caffeine consumption did not produce a significant effect on VO2max values. This finding aligns with previous literature suggesting that the response to caffeine in aerobic performance can depend on individual characteristics, dosage, and research methodology. According to the meta-analysis by Goldstein et al. (2010) and the guidelines of the International Society of Sports Nutrition, caffeine intake at doses of 3–6 mg/kg body weight may enhance endurance performance, although the effect is generally modest and not consistently observed across all studies [8].

The absence of a significant difference in VO2max can be explained by several factors. First, the moderate dose used in this study (3 mg/kg) may represent the lower threshold for ergogenic effects, especially in non-athlete populations. Second, the estimation of VO2max using the Cooper test has inherent limitations, as the results can be influenced by participant motivation, pacing variability, and environmental conditions [9]. Third, the small number of participants (n = 6) may have reduced the statistical power of the analysis, making it difficult to detect small yet meaningful effects [10]. In addition, individual differences in caffeine metabolism, such as variations in the CYP1A2 gene, could also influence the outcomes [11].

Caffeine acts primarily by blocking adenosine receptors in the central nervous system, which decreases the perception of fatigue and enhances alertness during physical activity. This mechanism is accompanied by an increase in epinephrine and norepinephrine release, which improves blood flow to the muscles and promotes the use of fatty acids as an additional energy source [1]. Through these combined effects, the body can sustain activity for a longer period before fatigue occurs, improving endurance and metabolic efficiency [3].

In the context of this study, caffeine did not significantly enhance endurance performance, although a positive trend was observed. This finding highlights the need for cautious interpretation, particularly when working with non-athletic participants, moderate doses, and indirect measurement methods.

B. The Effect of Caffeine on Recovery

Caffeine consumption resulted in a significant improvement in both HRrecov_1 and HRrecov_3 values. Because the paired t-test in this study analyzed the difference between the non-caffeine and caffeine trials, the negative mean difference indicates that post-caffeine heart rate recovery was faster. In other words, the participants' heart rate declined more rapidly after caffeine intake, reflecting an enhanced recovery process.

This finding is consistent with the study by Sarshin et al. (2020), which reported that caffeine administration at a dose of 3–6 mg/kg body weight can enhance cardiac autonomic

modulation at rest and accelerate autonomic recovery following anaerobic exercise [12]. The observed increase in HRrecov after caffeine consumption may be attributed to individual variability in caffeine response, influenced by habitual caffeine intake, sex, and genetic differences in caffeine metabolism particularly CYP1A2 polymorphisms [10].

Supporting evidence from Gonzaga et al. (2019) indicates that caffeine can modulate autonomic recovery after exercise, though the extent of its effect depends on individual cardiorespiratory fitness [6]. Participants with higher fitness levels exhibited faster parasympathetic reactivation than those with lower fitness, yet caffeine consumption improved recovery dynamics in both groups. Similarly, Sargent et al. (2022) found that a low caffeine dose (approximately 170 mg) did not impair parasympathetic nervous function recovery after moderate-intensity exercise, and even demonstrated faster heart rate recovery compared to the non-caffeine group [7].

Taken together, these findings suggest that caffeine may facilitate post-exercise recovery through enhanced autonomic regulation, particularly by promoting faster heart rate normalization. This highlights caffeine's potential role as a modulator of cardiovascular recovery mechanisms rather than a direct ergogenic aid for endurance performance.

V. STRENGTH AND LIMITATION

The strength of this study was the use of the Polar H10 heart rate monitor, which provided accurate and reliable assessment of heart rate recovery. However, this study had several limitations, such as the use of the Cooper test to estimate VO₂max instead of a gas analyzer direct measurement of VO₂max, which may have affected the precision of the endurance assessment.

VI. CONCLUSION

Based on the results, it can be concluded that caffeine consumption one hour before exercise can enhance post-exercise recovery but does not have a significant effect on endurance. However, further studies need to be conducted to reveal the underlying mechanism.

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