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Effects of Arabica and Chicory Coffee on Metabolic and Inflammatory Biomarker Responses to Acute Exercise: A Randomized Crossover Study

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Abstract

Purpose

Chicory coffee is increasingly consumed as a caffeine-free alternative to traditional coffee; however, its acute effects during exercise remain unclear. This study aimed to compare the effects of a single serving of Arabica coffee and chicory coffee on exercise performance, cardiometabolic responses, and inflammatory biomarkers in healthy men.

Methods

A single-blind, randomized, controlled crossover study was conducted with 22 healthy, moderately active men aged 18–25 years. Participants completed three intervention conditions: Arabica coffee (AC), chicory coffee (CC), and control (C), separated by a 3-day washout period. Beverages were consumed 45 minutes before shuttle run test. Blood glucose, lactate, oxygen saturation, blood pressure, and perceived exertion were assessed before and after exercise. Post-exercise venous blood samples were analyzed for lipoprotein lipase (LPL), tumor necrosis factor-alpha (TNF-α), adiponectin, and interleukin-6 (IL-6).

Results

Exercise performance outcomes did not differ significantly between conditions ($p > 0.05$). Blood glucose and lactate levels increased significantly after exercise in all groups ($p < 0.001$). LPL activity was significantly higher following AC consumption compared with CC and control conditions ($p = 0.038$). IL-6 levels tended to be lower in the CC condition compared with control ($p = 0.094$). Oxygen saturation decreased significantly only in the AC group ($p = 0.023$). No significant differences were observed for TNF-α or adiponectin.

Conclusion

Although neither Arabica nor chicory coffee improved acute exercise performance, both beverages produced distinct metabolic and inflammatory responses. Chicory coffee may represent a promising caffeine-free alternative for individuals sensitive to caffeine-related cardiovascular effects. Trial registration: ClinicalTrials.gov identifier NCT07094191.

Introduction

Coffee, the most consumed beverage worldwide after water, is well recognized for its ergogenic effects on metabolism and exercise performance [1]. Caffeine enhances fat oxidation, reduces glycogen utilization, and increases maximal oxygen uptake (VO_2max), a key indicator of aerobic capacity [2, 3]. Additionally, current findings demonstrate that caffeine intake can enhance muscular strength, movement velocity and power output during resistance exercise, supporting its ergogenic effect in athletic performance [4]. Ingestion of 3–6 mg/kg caffeine approximately 60 minutes before exercise has been shown to improve endurance performance through adenosine receptor antagonism and Na^+/K^+-ATPase activation [5].

Arabica coffee, which constitutes over 60% of global coffee production (ICO, 2025), has been reported to enhance VO_2max and reaction time in well-trained athletes, confirming its ergogenic potential. In a meta-analysis, caffeinated beverages providing at least 3 mg/kg of caffeine were shown to produce significant ergogenic effects on endurance performance, muscular strength, and team sport-specific actions, with similar performance benefits observed in both male and female athletes [6, 7]. Moreover, its rich chlorogenic acid content contributes to metabolic and antioxidant benefits by inhibiting carbohydrate-digestive enzymes and reducing oxidative stress (Karayiğit 2020). However, despite these benefits, the environmental cost of large-scale Arabica cultivation, such as its water and carbon footprint, has raised sustainability concerns [8].

In this context, caffeine-free alternatives that preserve coffee's functional properties are gaining scientific interest. One promising candidate is Chicory (Cichorium *intybus L.*), a plant-based beverage traditionally used as a coffee substitute since the 16th century [9]. It contains bioactive compounds such as inulin, sesquiterpene lactones, flavonoids, and chlorogenic acid derivatives that improve insulin secretion, glucose uptake, and lipid metabolism [10, 11]. Furthermore, caffeoylquinic acids modulate hepatic gluconeogenesis by downregulating glucose-6-phosphatase and phosphoenolpyruvate carboxykinase while enhancing mitochondrial respiration and energy metabolism [12]. Chicory coffee, therefore, represents a caffeine-free, polyphenol-rich beverage with potential metabolic and anti-inflammatory benefits, alongside a lower environmental impact compared with traditional coffee.

We hypothesized that caffeine-free, polyphenol-rich chicory coffee could serve as a functional alternative to Arabica coffee by modulating acute cardiovascular, metabolic, inflammatory, and performance responses to exercise. Our aim was to evaluate the practical effect of a single cup of Arabica or Chicory coffee before exercise, reflecting typical real-life pre-exercise consumption.

Materials and Methods

Study Design and Setting

The study was designed as a single-blind, randomized, controlled crossover trial and conducted at Haliç University, Istanbul. This trial was conducted in a single-blind manner: participants were not informed of the beverage identity, although sensory differences (taste, aroma, color) may have allowed some degree of recognition. Investigators were aware of beverage allocation; thus, blinding was maintained only at the participant level. Exercise performance tests were performed in the Sports Sciences Research and Application Laboratory, while biochemical analyses were carried out in the Molecular Biology and Genetics Research Laboratory of Haliç University. All experimental sessions were conducted under standardized conditions, including the same time of day, fasting state, and controlled physical activity prior to testing. The study was conducted between January 1 and September 30, 2024.

Participants

This experimental research was conducted on a sample of male students between the ages of 18–25 studying at Haliç University. The population of the study consists of individuals with a body mass index (BMI) in the range of 19–30 kg/m² who voluntarily agreed to participate in the study. Some exclusion criteria were considered in the selection of participants. Within the scope of the study, a total of 30 participants were pre-evaluated with the "Physical Activity Readiness Questionnaire for Everyone" [13]. Following the evaluation, 8 individuals were excluded

for medical reasons: two with a history of cardiovascular disease advised to exercise only under medical supervision, one reporting chest pain, one with a history of syncope in the last 12 months, one with an active musculoskeletal disorder that could worsen with exercise, two with type 2 diabetes and hypoglycemia history, and one with a mental health disorder requiring pharmacological treatment with poor disease control. The 22 male participants included in the study were individuals who did not have any chronic or metabolic diseases, did not use medication, did not smoke (no tobacco use within the past six months), did not report regular alcohol consumption, had low caffeine consumption (less than 100 mg per day), and were physically active but not a professional athlete. Daily caffeine intake was measured using a 24-hour food frequency questionnaire. Individuals who reported consuming less than one cup of coffee per day were classified as low caffeine consumers, corresponding to < 100 mg/day, consistent with previous estimates of caffeine content per cup of coffee [14].

The physical activity levels of the participants were evaluated through the Physical Activity (MET) Determination Form [15] and it was determined that the physical activity level of all individuals was in the "moderate" category.

Data Collection and Measurements

A one-hour theoretical and practical familiarization session on the shuttle-run test, addressing its purpose, content, and procedures, was conducted one week prior to the first experimental trial to ensure methodological consistency and minimize potential learning effects. Participants were asked to come with a fasting period of at least 8 hours on the day of the test. They were also informed that they should not make changes to their routine eating habits in the days before the test and that they should not consume foods and beverages containing caffeine that could affect performance. Coffees were consumed 45 minutes before the shuttle run test performance measurement. All exercise trials were conducted in the morning (10:00 a.m.), a time window chosen to minimize variability due to circadian influences on metabolism and cardiovascular responses [16]. A three-day washout period was applied after each performance trial. This duration was selected based on evidence that > 48 h is sufficient for caffeine clearance and also allows for adequate recovery from exercise-induced fatigue in young, moderately active adults, thereby minimizing carryover effects [17]. To determine the characteristics of the participants, a demographic information form and 24-hour food consumption records were taken by one-to-one interview method before each shuttle running test to evaluate their eating habits, history, and food consumption. The demographic information form was completed once, prior to the first experimental trial. To minimize dietary variability, participants also provided 24-hour dietary records before each shuttle-run test. The 20 m shuttle-run test was administered on a flat, non-slippery surface with a 20 m course marked by cones and paced by standardized audio signals. Participants ran back and forth in accordance with the beeps, while the running speed increased progressively each minute. The test was terminated when a participant failed twice to reach the line in time The final level achieved was used to estimate VO_2max, which was calculated using the following formula: 3.46 * (level + # round / (level * 0.4325 + 7.0048)) + 12.2 [18].

Following the shuttle run test, venous blood samples were collected within 5 minutes by a trained healthcare professional. The blood samples brought to the laboratory were centrifuged with a microcentrifuge device at 2000 x g for 15 minutes and the plasma part was separated. Lipoprotein lipase, TNF-α, Adiponectin and IL6 protein levels were measured from plasma with commercially purchased ELISA kits (ELK Biotechnology, Turkey). For each kit, the protocol described by the manufacturer was followed. The method is based on antigen–antibody interaction, and the enzyme-induced color change enables sensitive and reliable quantification of the target biomolecules.

Lactate test was performed using a portable lactate analyzer (Lactate Scout 4, Germany) to determine the degree of fatigue of the participants before and within the first 5 minutes after exercise. In order to subjectively evaluate fatigue, the Borg Perceived Difficulty Scale [19]. was used immediately after exercise. In order to observe sudden changes in blood glucose levels, blood collected on the tip of the finger was measured before and immediately after exercise. Heart rate, systolic and diastolic blood pressure, and oxygen saturation were measured with oximetry before and after exercise.

Intervention Beverages

In this study, participants were given 180 ml of Arabica coffee and Chicory root coffee (Cichorium intybus L.) before the intervention. This selected amount reflects the average volume corresponding to a serving of coffee consumption in both national and international literature. Observational studies conducted around the world show that individuals' daily coffee consumption is generally in the form of single portions in the range of 150–240 ml [20]. Therefore, comparing the effects of both types of coffee at the level of single serving consumption increases suitability for real-life scenarios and minimizes gastrointestinal disturbances or side effect events associated with stimulant effects of coffee [21]. Chicory coffee (prepared using 20 g of roasted chicory root per 180 mL serving) contains higher levels of inulin and phenolic compounds compared to black Arabica coffee. The Arabica coffee provided an estimated caffeine dose of approximately 80–100 mg per 180 mL serving, corresponding to ~ 1.2–1.5 mg/kg body weight in the present sample, based on established reference values for brewed Arabica coffee.

This relatively low dose was intentionally selected to reflect habitual, real-life consumption patterns rather than the higher ergogenic doses commonly used in performance-focused studies. Accordingly, the findings are intended to reflect ecological validity and everyday consumption conditions rather than optimized performance enhancement scenarios. A relatively low caffeine dose was selected to minimize its potential confounding effects on metabolic outcomes and to better isolate the influence of non-caffeine bioactive components.

The nutritional values referenced in this study were obtained from laboratory analyses provided by the local Chicory coffee producer and from the USDA FoodData Central database for Arabica coffee [22]. The participant flow throughout the study phases is shown in Fig. 1 (CONSORT Flow Diagram).

Power Analysis and Statistical Analysis

Sample size was calculated a priori using G*Power (v3.1.9.7) for a repeated-measures ANOVA with two within-subject factors (condition: control, AC, CC; time: pre, post). Assuming a medium effect size (f = 0.25), α = 0.05, and power = 0.80, the required sample size was n = 21. To account for potential attrition, 22 participants were recruited, thereby ensuring adequate statistical power. In addition to conventional 95% confidence intervals (CIs), 90% CIs for effect sizes were reported to provide more precise estimates in small-sample exploratory trials. These 90% CIs were not used to redefine statistical significance thresholds, but to complement the interpretation of effect sizes.

As a sensitivity check, a simulation-based power analysis was performed in R (Superpower package, 10,000 iterations), using the observed means, standard deviations, and correlation structure of the repeated measures. Results confirmed that the available sample size provided sufficient power for the main hypothesis.

All analyses were conducted in SPSS 27 (IBM Inc., Chicago, IL, USA) and R 4.4.2. Descriptive statistics are presented as mean ± standard deviation (SD), median, and range, while categorical variables are shown as

frequency and percentage. Normality of distributions was tested using the Shapiro–Wilk test, and multivariate normality using the Mardia test. For normally distributed paired data, the dependent-sample t-test was applied; otherwise, the Wilcoxon signed-rank test was used. Repeated-measures ANOVA was applied for within-subject comparisons, with Greenhouse–Geisser corrections when sphericity was violated. For non-parametric multi-group comparisons, the Kruskal–Wallis test was used. Correlations were assessed with Pearson or Spearman coefficients depending on distribution. Correlation strength was classified as very weak (0.00–0.19), weak (0.20–0.39), moderate (0.40–0.59), strong (0.60–0.79), and very strong (≥ 0.80). For secondary outcomes, multiple comparisons were adjusted using Bonferroni corrections. Effect sizes are presented with both 95% and 90% CIs. The statistical significance threshold for the primary outcome was set at $p < 0.05$ (two-tailed) [23].

Results

A total of 22 moderately active male participants aged 18–25 years were included in the study. The mean age was 21.3 ± 1.5 years, body mass 72.4 ± 6.8 kg, height 176.2 ± 5.9 cm, and BMI 23.4 ± 2.1 kg/m². Baseline characteristics are presented in Table 1.

Table 1. Results of mixed-repeated measurements analysis of variance (Pillai's Trace) of pre- and post exercise cardiometabolic responses in study groups

Parameter	Group	Pre-exercise	Post-exercise	5 min post-exercise	F	p	η²
Heart rate (beats/min)	C	83.7 ± 11.9	174.5 ± 23.6	121.6 ± 11.3	1.200	0.332	0.040
	AC	82.2 ± 13.3	165.8 ± 55.8	119.4 ± 28.5			
	CC	78.2 ± 10.4	182.9 ± 12.3	120.1 ± 12.9			
Systolic BP (mmHg)	C	117.9 ± 11.7	129.9 ± 14.9	–	0.025	0.456	0.050
	AC	114.2 ± 11.9	130.9 ± 15.9	–			
	CC	114.4 ± 9.1	121.1 ± 16.0	–			
Diastolic BP (mmHg)	C	64.9 ± 10.9	–	69.7 ± 17.9	0.010	0.723	0.010
	AC	63.8 ± 10.7	–	72.0 ± 19.7			
	CC	66.6 ± 9.9	–	63.7 ± 10.1			
Lactate (mmol/L)	C	3.2 ± 2.5	–	13.5 ± 2.1	0.009	0.764	0.007
	AC	4.1 ± 5.2	–	14.7 ± 3.1			
	CC	2.7 ± 2.5	–	13.4 ± 2.8			
Oxygen saturation (%)	C	97.5 ± 1.0	96.1 ± 2.9	–	0.014	0.651	0.010
	AC	97.7 ± 0.8	96.7 ± 2.0	–			
	CC	97.5 ± 0.9	96.8 ± 2.1	–			
Blood glucose (mg/dL)	C	99.6 ± 8.8	124.8 ± 17.5	–	0.021	0.518	0.010
	AC	102.4 ± 10.5	126.7 ± 16.5	–			
	CC	99.2 ± 11.7	118.0 ± 13.9	–			

C: control; AC: Arabica coffee; CC: chicory coffee; BP: blood pressure. Values are mean ± SD.

F, p and η² represent group × time interaction (mixed repeated-measures ANOVA). p < 0.05 was considered significant. "–" indicates not measured.

*Chicory coffee (CC), Arabica coffee (AC), Control(C),*F: Analysis of variance test statistics; p: Level of significance; η² (eta squared): Effect size (refers to the power of interaction). The significance level was accepted as p<0.05. "–: not measured, BP: Blood Pressure

Exercise performance outcomes, including shuttle run laps, BORG scores, and VO_2max, did not differ significantly between groups (p > 0.05) (Table 2).

Table 2. Univariate and multivariate comparison of Shuttle Run laps, BORG scores, and VO_2max values between study groups

	Groups						F/χ^2	p
	C		AC		CC			
	Mean ±SD	Q2 (Min-Max)	Mean ± SD	Q2 (Min-Max)	Mean ± SD	Q2 (Min-Max)		
Shuttle Run (number of laps)	54,2±10,50	56(32-74)	59,40±13,80	61(28-82)	56,40±11,80	60(30-81)	$1,006_F$	0,372
BORG Test (scale 1-10)	7,90±1,00	8(6-10)	8,20±0,80	9(7-9)	8,20±1,00	8(6-10)	$2,314_{\chi^2}$	0,317
VO_2 max ($mL \cdot kg^{-1} \cdot min^{-1}$)	38,6±3,50	39(28-46,5)	39,10±3,70	40(31-46,5)	38,70±3,40	39(29-45,9)	$0,319_{\chi^2}$	0,836

Model F_1: 0,399; p = 0,878; Cohen f = 0,14 (Bitiş turu, BORG ve VO_2max)

Model F_2: 0, 484; p = 0,747; Cohen f = 0,12 (BORG ve VO_2max)

Model F_3: 0,608; p = 0,657; Cohen f = 0,14 (Bitiş turu ve BORG)

Model F_4: 0,359; p = 0,837; Cohen f = 0,11 (Bitiş turu ve VO_2max)

F: One-way ANOVA test; χ^2: Kruskal-Wallis H Test Chi-square Statistical Value; Chicory coffee (CC), Arabica coffee (AC), Control(C)

Post-exercise systolic blood pressure increased significantly in all groups (C: $p < 0.001$; AC: $p < 0.001$; CC: $p = 0.039$), whereas no significant changes were observed in diastolic blood pressure. Lactate levels increased significantly in all groups ($p < 0.001$). Oxygen saturation decreased significantly only in the AC group ($p = 0.023$). Blood glucose levels increased in all groups after exercise ($p < 0.001$) (Table 3).

Table 3. Pre- and post-exercise clinical variables: Intragroup comparisons in the C, AC and CC groups

Parameters	Group	Pre-Exercise (Mean ± SD)	After Exercise (Mean ± SD)	Test	p
Systolic (mmHg)	C	117,91±11,72	129,91±14,92	z=-3,842	**<0,001*** **
	AC	114,18±11,92	130,86±15,89	t=-4,447	**<0,001*** **
	CC	114,36±9,14	121,09±16,02	t=-2,204	0,039*
Diastolic (mmHg)	C	64,91±10,90	69,73±17,87	z=-0,503	0,615
	AC	63,77±10,74	71,95±19,70	z=-1,381	0,167
	CC	66,64±9,87	63,73±10,11	t=1,460	0,159
Lactate (mmol/L)	C	3,20±2,54	13,53±2,08	z=-4,108	**<0,001*** **
	AC	4,05±5,21	14,72±3,07	z=-4,075	**<0,001*** **
	CC	2,71±2,46	13,44±2,77	z=-4,075	**<0,001*** **
Oxygen (%)	C	97,50±0,96	96,09±2,86	z=-1,822	0,068
	AC	97,68±0,78	96,68±2,01	z=-2,273	0,023*
	CC	97,45±0,86	96,82±2,06	z=-1,084	0,278
Blood Glucose (mg/dL)	C	99,55±8,79	124,77±17,47	t=-7,444	**<0,001*** **
	AC	102,36±10,54	126,68±16,53	t=-5,737	**<0,001*** **
	CC	99,23±11,65	118,00±13,88	z=-4,016	**<0,001*** **

t: Dependent Sample t-Test; z: Wilcoxon Signed Ranks Test**; *p<0,05;** ***p<0,001;** chicory coffee (CC), Arabica coffee (AC), and Control(C)

In multivariate analysis, no statistically significant differences were observed between groups for combined inflammatory and metabolic biomarkers (p = 0.087). In univariate analyses, LPL levels differed significantly between groups (p = 0.038), with higher values observed in the AC group. IL-6 levels were lower in the CC group compared with control, although this difference did not reach statistical significance (p = 0.094). No significant differences were found for TNF-α or adiponectin (Table 4).

Table 4. Comparison of metabolic biomarker levels according to study groups

	OD (Mean ± SD)		Median (min-max)	F-H	p
LPL – C[b]	0,53±0,37		0,41 (0,15-1,36)		
LPL – AC[a]	0,86±0,73		0,45 (0,09-2,49)	H=0,662	**0,038****
LPL – CC[b]	0,50±0,30		0,44 (0,09-1,30)		
TNF-α – C	0,16	0,11	0,09 (0,06-0,37)		
TNF-α – AC	0,12 0,08		0,09 (0,06-0,29)	H=1,080	0,267
TNF-α – CC	0,11 0,08		0,08 (0,06-0,35)		
IL-6 – C	0,30 0,24		0,20 (0,06-0,78)		
IL-6 – AC	0,20 0,15		0,16 (0,06-0,57)	H=1,819	**0,094***
IL-6 – CC	0,18 0,16		0,12 (0,06-0,66)		
Adiponectin – C	0,35 0,14		0,33 (0,07-0,64)		
Adiponectin – AC	0,35 0,17		0,35 (0,04-0,66)	F=0,422	0,581
Adiponectin – CC	0,32 0,15		0,31 (0,04-0,64)		

$F_{2;T}$ **TNF-α**: 1,351; p = 0,267

$F_{2;IL6}$: 2,452; p = 0,094*

$F_{2;}$ A**diponectin:** 0,548; p = 0,581

$F_{2;\ LPL}$: 3,445; p = 0,038**

In pairwise group comparisons, there was a limited significance between LPL levels between the AC and CC groups (p=0.061).

A difference in IL-6 levels was found between the C and CC groups in the margin of significance (p=0.140).

F: One-Way ANOVA Test; H: Kruskal Wallis Testi; F1: MANOVA; F2: Univariate ANOVA; *:p<0,1; **:p<0,05

a: Significant difference; b: The group with no significant difference. "* / **: Holm-Bonferroni" has been corrected.

Chicory coffee (CC), Arabica coffee (AC), and Control(C)

As illustrated in Figure 2, LPL levels tended to be higher following Arabica coffee consumption, whereas IL-6 levels appeared lower in the chicory coffee condition. Pairwise comparisons indicated higher LPL levels in the AC group compared with CC and control, although the difference between AC and CC did not reach statistical significance (p = 0.061). IL-6 levels were lower in the CC group compared with control, without reaching statistical significance (p = 0.140)

Correlation analyses showed strong positive associations between changes in oxygen saturation (ΔO_2) and VO_2max across all groups (p < 0.001). No consistent associations were observed between VO_2max and other variables, including lactate, glucose, and heart rate. As shown in Figure 3, blood glucose levels increased after exercise across all study conditions, with a comparatively smaller increase observed in the chicory coffee condition.

Discussion

This study demonstrated that pre-exercise consumption of either AC or CC, compared with no coffee, did not significantly affect acute exercise performance or physiological parameters in healthy young men. However, distinct coffee varieties elicited divergent responses in metabolic and inflammatory biomarkers. AC was associated with increased LPL activity, suggesting potential benefits for lipid metabolism, while CC consumption tended to reduce IL-6 compared with control, suggesting a potential anti-inflammatory effect. These findings highlight that although coffee type may not directly improve short-term exercise outcomes, it may modulate biochemical pathways relevant to metabolic regulation and inflammation. This study is the first to evaluate the effects of CC on exercise performance and metabolic parameters. Therefore, the available literature on this topic is limited. However, research on the health effects of Chicory and research on coffee contribute to the literature review.

Studies have consistently shown that an increased number of running laps is associated with greater cardiovascular endurance and higher VO_2max [24]. In line with this, our study demonstrated a strong and significant positive correlation between the number of laps completed and VO_2max, confirming that lap-based field tests provide a reliable indicator of aerobic capacity. Conversely, only a weak positive association was observed between perceived exertion (Borg scores) and VO_2max. This suggests that while individuals reporting higher subjective effort tended to have slightly greater aerobic capacity, perceived fatigue does not always align with objective physiological markers [25].

In this study, systolic blood pressure increased significantly across groups, but the most pronounced elevation was observed after AC consumption. This aligns with evidence that elevated blood pressure can impair exercise performance and delay recovery [26]. The likely mechanism involves caffeine's antagonism of A1 adenosine receptors, which are structurally like adenosine. By blocking these receptors, caffeine promotes vasoconstriction, leading to acute increases in systolic pressure [27]. This mechanism also explains for the slight decrease in peripheral oxygen saturation observed with AC. In contrast, CC, which is caffeine-free, did not produce such hemodynamic changes, suggesting it may be a safer option for individuals sensitive to caffeine-induced cardiovascular stress.

In a study Brussels Chicory juice improved exercise time and reduced post-exercise lactate levels in both men and women [28]. In this study, the highest post-exercise lactate was observed in the AC group, aligning with studies showing that caffeine may enhance glycolytic activity and increase lactate accumulation during high-intensity work [29]. However, both AC and CC ultimately demonstrated comparable post-exercise lactate values, indicating that coffee type did not markedly alter anaerobic contribution under maximal effort.

Experimental studies indicate that Chicory extract reduces pro-inflammatory cytokines such as TNF-α and IL-6, partly through the inhibition of the NF-κB signaling pathway [30]. Another study reports that chicory (Cichorium pumilum) extract suppresses LPS-induced inflammation and exerts a protective effect against gut–liver axis–related hepatic fibrosis by inhibiting the MAPK signaling pathway [31]. In a study, Chicory seed extract reduced ALT and AST levels in patients with NAFLD, indicating an improvement in liver function [32].

In the present study, LPL activity was significantly higher in the AC group compared to the C and CC groups ($p = 0.038$). This result agrees with in-vitro findings showing that the combined effect of chlorogenic acid and caffeine can suppress adipogenesis via PPAR-γ. [33]. Caffeine has been shown to exert anti-adipogenic effects by modulating the intestinal microbiota, leading to improved metabolic regulation in obesity [34]. Since CC contains

chlorogenic acid but lacks caffeine, the increase in LPL observed in the AC group may be attributed to the synergistic action of caffeine and chlorogenic acid. We found a significant reduction in IL-6 levels in the CC group. IL-6 is a myokine released during exercise that helps regulate energy metabolism and can exert anti-inflammatory effects; therefore, post-exercise changes in lactate and aerobic capacity may also be partly influenced by IL-6–mediated metabolic signaling [35]. Exercise itself induces IL-6 secretion, which may impair performance by promoting systemic inflammation and influencing heart rate [36]. While TNF-α does not directly impair exercise performance, it can induce muscle breakdown and fatigue [37]. In contrast, adiponectin has been positively associated with exercise capacity, no direct link between inflammatory markers and exercise fatigue. Considering adiponectin's role in enhancing mitochondrial oxidative capacity and attenuating inflammation through AdipoR1-AMPK signaling, its previously documented pro-myogenic and metabolic regulatory effects may partly underpin the differential post-exercise lactate responses and aerobic capacity patterns observed in our study [38]. Supporting this, a Japanese cross-sectional study demonstrated that coffee consumption was positively associated with adiponectin levels and inversely related to leptin and hs-CRP [39]. In line with these results, our study observed the highest TNF-α and IL-6 levels in the C group, which may indicate systemic inflammation. This suggests that coffee and Chicory consumption may exert differential effects on inflammatory processes, possibly through their distinct bioactive components.

In a study, oral glucose tolerance test (OGTT) was performed before and after caffeine (3 mg/kg) or placebo. Caffeine increased diastolic blood pressure but did not alter heart rate variability, while improving glucose tolerance [40]. In our study, blood glucose levels significantly increased after exercise in all groups, whereas no significant differences were observed between groups. This pattern indicates that the acute effect of exercise itself was the dominant factor influencing glycemic changes. The fact that blood glucose did not decrease in the CC group may be considered a beneficial outcome. Maintaining glucose availability during exercise is critical for sustaining performance and preventing hypoglycemia [41].

Limitations and Recommendations

Future studies should include larger and more diverse samples and investigate the chronic (≥ 4 weeks) effects of regular AC and CC consumption on exercise performance and metabolic or inflammatory markers. Moreover, future work should consider sex- and age-related differences, hormonal status, and psychological factors such as mood and motivation, which may influence perceived exertion and performance outcomes.

Conclusions

In healthy young men, pre-exercise consumption of AC or CC did not significantly affect exercise performance. Nonetheless, distinct coffee varieties elicited differential responses in specific inflammatory and metabolic biomarkers. AC intake was associated with elevated LPL levels, whereas higher LPL supports enhanced fatty acid utilization and metabolic efficiency, which over time may influence training adaptation. The reduction in IL-6 observed in the CC group may reflect a blunted post-exercise inflammatory response, which could support more efficient recovery and reduced muscle catabolic signaling. These findings indicate that while coffee type does not markedly influence acute exercise performance, it may modulate biochemical pathways relevant to metabolic and inflammatory regulation. CC may be considered as a safe pre-exercise beverage for individuals sensitive to caffeine-induced cardiovascular stress.

Declarations

Author Contributions: F.Ö.Ö. conceived of the idea and conducted the study. F.Ö.Ö. wrote the initial draft of the manuscript. C.O. provided academic supervision and guidance throughout the study. H.İ.O. and İ.T.T. contributed to the methodology of the study. All authors read and approved the final manuscript.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in this study.

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During the preparation of this work, the authors used ChatGPT (OpenAI) for minor language editing. The authors take full responsibility for the content of the published article.

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Figures

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Figure 1

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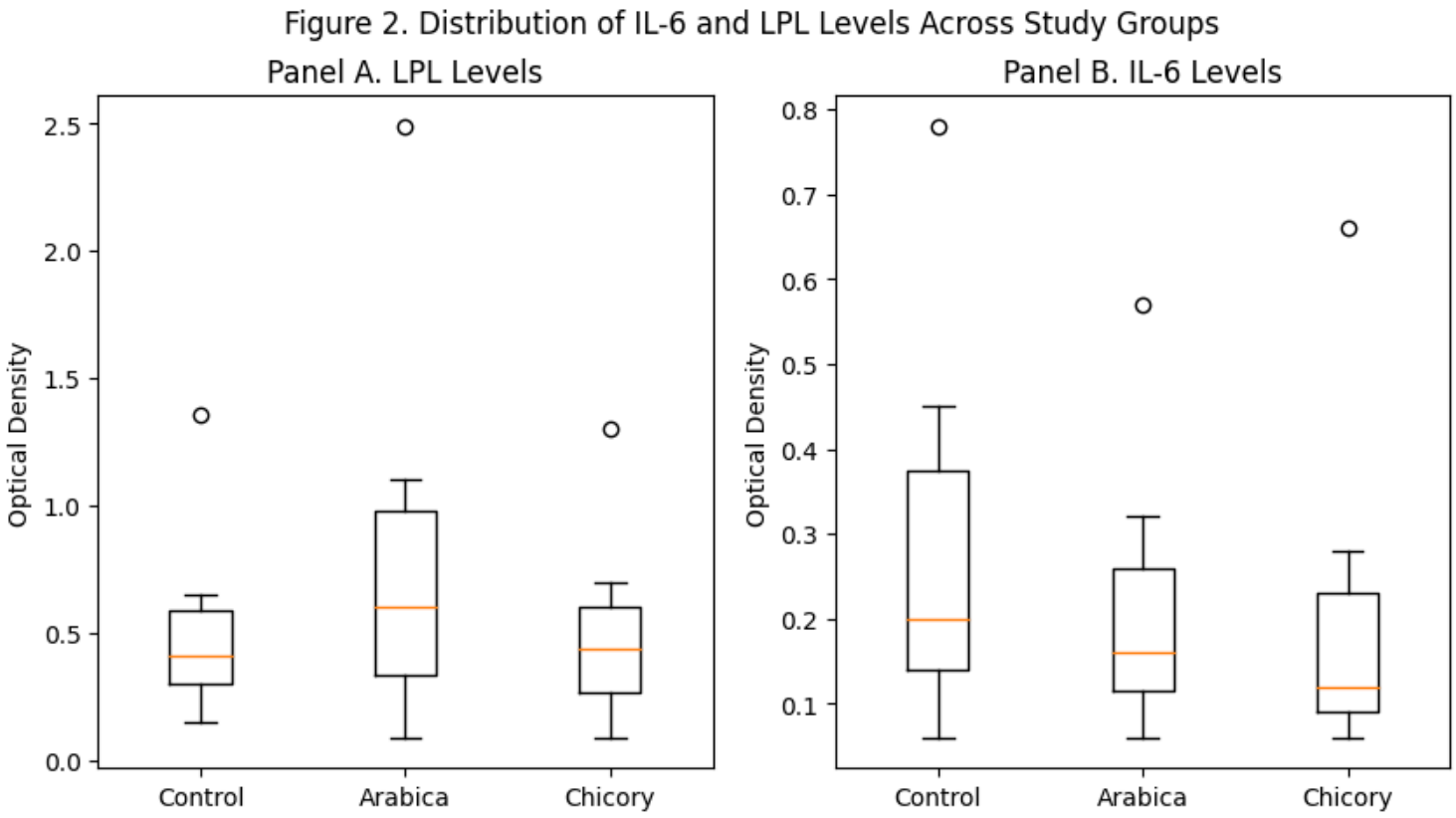


Figure 2

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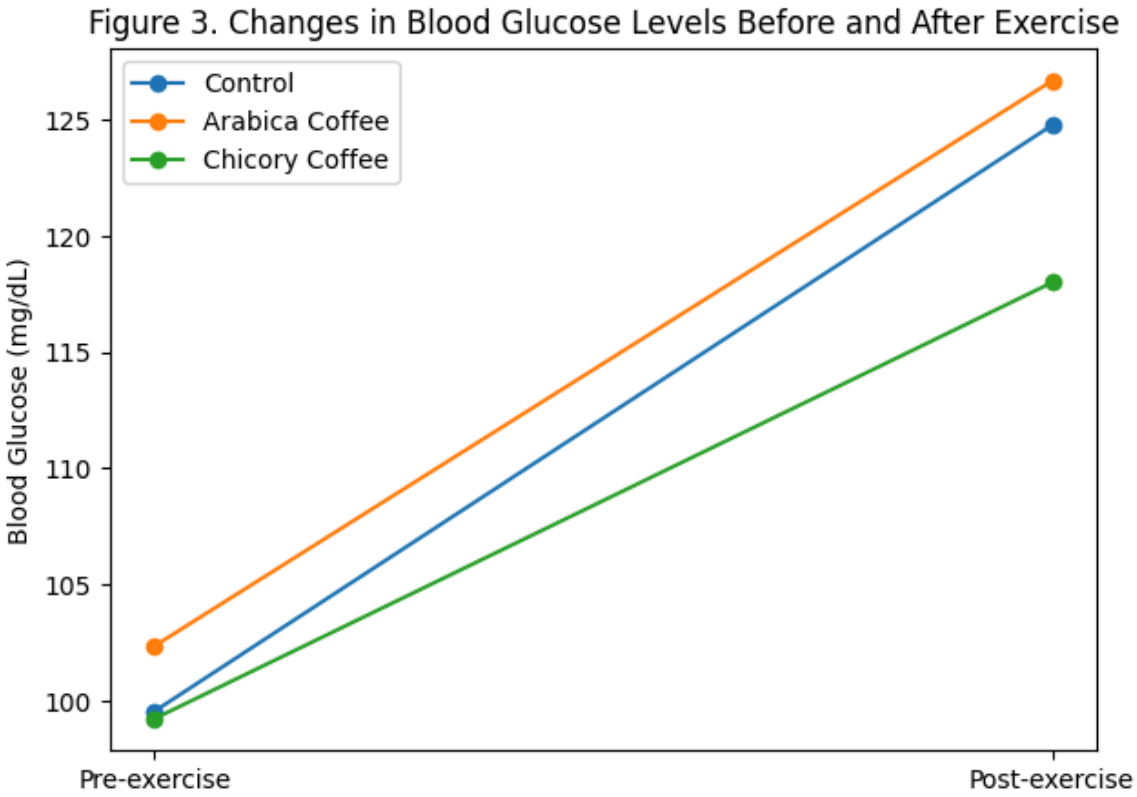


Figure 3

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