

Research Article

Synergistic effects of cinnamon supplementation and Tabata HIIT on metabolic health and performance outcomes in military cadets: Bridging traditional medicine and modern physiology

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Abstract

The integration of herbal supplementation with exercise training may offer a novel hybrid strategy that bridges traditional medicine and modern performance science to enhance recovery and physical outcomes. This study aimed to evaluate the synergistic effects of cinnamon supplementation and Tabata-style high-intensity interval training (HIIT) on metabolic and performance outcomes in young male military cadets. Forty-eight healthy cadets were randomly assigned to four groups: Tabata training (T), cinnamon supplementation (S), Tabata+cinnamon (TS), and control (C). The intervention lasted six weeks, consisting of thrice-weekly Tabata sessions (87–100% HRmax) and daily oral cinnamon supplementation (1.5 g/day). Assessments conducted before and after the intervention included body composition, VO_2 max, post-exercise blood lactate levels, and combat readiness scores based on the Army Combat Fitness Test. Statistical analysis employed paired t-tests and ANCOVA at a significance level of $p < 0.05$. Significant improvements were observed in the TS group compared to control: VO_2 max increased ($p=0.001$), post-exercise lactate decreased (-1.93 mmol/L, $p=0.001$), and combat readiness scores improved substantially (+63.6 points, $p=0.001$). Comparable but less pronounced improvements were observed in the Tabata-only and cinnamon-only groups. No adverse effects were reported. The findings suggest that cinnamon—a time-honored medicinal spice—may potentiate the effects of high-intensity training by improving aerobic capacity, lactate clearance, and combat readiness. This study provides translational evidence supporting cinnamon as a safe, natural, and affordable traditional functional food that can enhance physical performance and metabolic resilience in tactical populations. The integration of traditional herbal supplementation with modern training paradigms offers a promising avenue in the evolving field of evidence-based traditional medicine.

Key Words: Cinnamon supplementation, Traditional medicine, Functional nutrition, High-intensity interval training, Tabata protocol

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Introduction

Two linked pillars in conventional methods of health care and performance improvement have long been known as nutrition and herbal medicine. In ancient Persian and Chinese medicine, cinnamon has been recognized as a classic remedy that sustains vitality, regulates metabolism, and enhances recovery from physical stress by means of several plant-based compositions used in Ayurvedic medicine. Cinnamon supplement is a highly regarded versatile spice and medicinal herb with uses in both cooking and medicine. Modern scientific studies increasingly demonstrate that its antioxidant, anti-inflammatory, and insulin-sensitizing properties establish a link between evidence-based nutrition and ancient medicinal wisdom (Guo et al., 2024; Pagliari et al., 2023; Khedkar et al., 2023; Hussain et al., 2019; Sabzevari Rad et al., 2025; Sabzevari Rad et al., 2024).

The physical and psychological demands placed on military and tactical groups often go beyond the bounds of what is physiologically possible. Soldiers and cadets often face persistent energy depletion, oxidative stress, and inflammation due to intense physical exertion, insufficient rest, and inconsistent access to nutrient-rich meals (Shang et al., 2021; Tuzcu et al., 2017). Through the incorporation of functional foods and natural treatments, traditional medicine highlights the idea of functional resilience, which is the body's capacity to adapt and heal under stress. The use of natural ergogenic helpers and modern functional nutrition are both in line with this strategy.

Prior dietary evaluations of Iranian cadets have found major inadequacies in micronutrients and variety of functional foods (Sabzevari Rad et al., 2025). This highlights the possible benefit of interventions that are culturally appropriate, natural, and accessible and that can fill these nutritional gaps without requiring significant logistical adjustments. Due to its historical usage as a medicinal spice, cinnamon has exceptional potential in this area. It is known that its bioactive components, particularly cinnamaldehyde, eugenol, and a variety of polyphenols,

-nols, improve glucose metabolism, aid mitochondrial activity, and lessen oxidative stress (Guo et al.,2024; Pagliari et al.,2023; Khedkar et al.,2023; Hussain et al.,2019). These methods are immediately related to maintaining performance and recuperation throughout strenuous physical activities.

Synergistic approaches that combine herbal treatments with structured exercise regimens may yield enhanced physiological benefits from both traditional medicine and modern sports physiology perspectives. In this regard, HIIT (high-intensity interval training) has become a specialized method. Tabata-type interval training (20 minutes of maximum effort and 10 seconds of recovery, repeated eight times) has shown consistent and beneficial effects on both aerobic and anaerobic measures, including increases in VO_2 max, lactate threshold, mitochondrial biogenesis, fat oxidation, and often with a total session duration of less than 30 minutes (Tabata,2019; Gibala et al.,2014; Viana et al.,2019). The fact that Tabata training is very effective and requires very little equipment makes it particularly suitable for military use, where training time is limited, logistical problems are common and physical fitness is of the utmost importance for the success of the mission (Domaradzki et al., 2020; Murawska-Ciałowicz et al., 2019). While this scientifically proven method enhances both aerobic and anaerobic capacity, it also induces substantial metabolic stress—an effect that could theoretically be mitigated by herbal treatments known to promote cellular repair and improve energy efficiency (Tabata, 2019).

Despite the fact that cinnamon has been studied extensively in metabolic and cardiovascular settings (Guo et al., 2024; Dorri et al., 2018; Tuzcu et al.,2017; Shang et al.,2021), its combination with exercise training in tactical groups has not been thoroughly examined. The current study seeks to examine the synergistic impact of cinnamon supplementation and Tabata-style high-intensity interval training (HIIT) on metabolic by combining conventional herbal pharmacology with evidence-based exercise physiology. Health and physical performance among young male military cadets. This research is an attempt to integrate a traditional medicinal substance into a contemporary functional environment. Strengthening the increasing synergy between conventional medicine and performance physiology.

Materials and methods

Participants

Out of the 60 screened cadets, 48 fell within the inclusion criteria and they were randomized into 4 groups (age:22.8±1.32 years, weight: 78.28±4.09 kg, height: 177.70±3.74cm, BMI:23.42±1.06 kg/m²): Tabata training (n=14), combined Tabata-cinnamon (n=14), cinnamon (n=10), and control (n=10), and Those excluded were: diabetes mellitus, thyroid diseases, cigarette smoking, high blood pressure, pain in joints and skeletal injury.

None of the participants expressed anything other than a very good health status, which proved to be true on medical testing. Three athletes also dropped out because of unrelated medical leave (one with Tabata and two with Tabata-cinnamon). In this way, 45 of them (T=13 ‘TS=12 ‘S=10 ‘C=10) participated in the research and entered the ultimate analysis. Participants of the study were given the consent to participate in tabata training, supplementation with cinnamon and ACFT test. When they received an acquaintance with all the conditions of the research, they stated that they could withdraw at any phase and offered their written consent to participate in the experiment. The studies were in compliance with the declaration of Helsinki. This research was accepted by Research Ethics Committees of Islamic Azad University-Ardabil Branch on 3 March 2025 (IR.IAU.ARDABIL.REC.1403.229).

The body composition of the participants, the combat readiness, blood lactate measure, and the Cardiorespiratory fitness were taken at the beginning of the training, and after the 6-week exercising time. ACFT testing was performed between (8:00 AM and 10:00AM). The analysis of body composition was conducted in the morning (8:00 AM and 10:00 AM) using Body Composition Analyzer (InBody 380, South Korea) as per the manufacturer guide. Cadets thus were advised not to eat and eat and drink 4-hours before testing, were not high intensity exercised 24-h before testing, and were to be in normal hydration. Medical scales assessed body mass and standing height of every cadet to the nearest 0.1kg and 0.1cm, respectively (Seca 284, Germany).

Combat readiness assessment

Before beginning the ACFT, cadets completed the dynamic warmup routine from the Army called the "preparation drill," which consisted of ten bodyweight exercises: bent leg body twist, pushup, bend reach, windmill, rear lunge, squat bender, high jumper, forward lunge, rower, and prone row (Withrow et al., 2023). The combat readiness of the cadets was evaluated using the Army Combat Fitness Test (ACFT). ACFT has six events that measure how strong, powerful, and fit cadets are in terms of muscles, anaerobic capacity, and aerobic endurance. The events are the 3 maximum repetition deadlifts, standing power throw, pushups, sprint-drag-carry, leg tuck, and a Two-mile run. The total testing time is no more than 120 minutes. Cadets do these events in groups so they can rest in between. Each test is scored 100, and the total score is 600. (23 minutes between all tests except after the leg tuck where they relax for 10 minutes) (Withrow et al., 2023).

1. Cadets complete three straight repetitions following a 10-minute warm-up using a hexagonal bar deadlift.
2. Standing Power Throw: Cadets throw a 10pound medicine ball backwards over their head, aiming for distance. They have two tries.

3. Pushups: Cadets strive to do as many repetitions as they can in a 2-minute timed event while keeping correct posture.
4. Sprint-Drag-Carry: A timed 250-meter shuttle including kettlebell carries, lateral shuffles, sled dragging, and sprints.
5. Leg Tuck: Cadets hang from a bar and lift their knees to their elbows.
6. Two-Mile Run: A timed event when cadets cover two miles at their own pace along a level course, with timings noted at both start and end. Army Techniques Publication 722.01 specifies certain methods and scoring criteria for all events following Army standards.

Cardiorespiratory fitness assessment

Maximal aerobic capacity (VO₂max) was estimated using the Two-Mile Run test, a validated field-based protocol commonly employed in military fitness evaluations (Knapik et al., 2022). Participants completed the run on a flat outdoor course under standardized conditions. VO₂max was calculated using the following regression equation derived from military populations:

$$VO_{2max}(ml \cdot kg^{-1} \cdot min^{-1}) = 100.5 - (2.91 \times \text{Two-Mile Run Time in minutes})$$

This method has demonstrated strong predictive validity and operational relevance for assessing cardiorespiratory fitness in tactical settings. All tests were conducted in the morning hours (08:00–10:00), and participants were instructed to avoid high-intensity exercise 24 hours prior to testing.

Lactate concentration assessment

The concentration of blood lactate present in biochemical laboratory conditions was determined based on the colorimetry method (in a Mini Photometer Plus LP20 (Dr. Lange, Germany)) using a Lactate Cuvette Test kit (Hach Lange GmbH, Dusseldorf, Germany). La concentration was measured 5 min after the ACFT test at baseline and post intervention.

Tabata training program

This was a 6-week training that was conducted thrice a week during the evenings within 16:00-17:00 slot. A total of 18 trainings were conducted. Each exercise session was 1 hours with a 10-minute warm-up, 30-40-minute exercise training primary In Tabata form and 10 minutes final cold down. Throughout the majority of the session, the cadets were to go through eight series of exercises in a training session. The series, which were 4 min and 6 s in duration, and included eight repeats of exercises during

which 20 s were spent at training and 10 s at rest (Feito et al., 2019). The primary purpose of every training process was to achieve maximum intensity exercising.

There was a 1 min passive pause between each set. Each set included 8 exercises: the walking lunges, Burpee, Bicycle crunches, Inchworm to Push-ups to Opposite Toe Touch, Triceps Dips, Mike Tyson push-ups, Side plank, and Lying prone Y to T to W. The last 10-minute segment of the training involved stretching and relaxing exercises. The level in every training session was measured by the heart rate control and averaged per cadets and throughout sessions. With this purpose, Polar H10 (Polar, Malaysia) measuring apparatus was applied. Calculation of the energy expenditure was calculated by the average heart rate of the session per cadet which was average. Tabata functional training protocols is shown in Figure 1.

Cinnamon supplementation intervention

The latter was used in three doses per day, 1.5 grams each, in 500 mg capsules, taken at the end of each meal throughout the 6 weeks. The supplier certified purity and consistency of capsules and shipped these weekly under supervision of researchers (Maieran et al., 2017).

Statistical analysis

Table 1. Chosen anthropological and physiological parameters at the baseline and after 6-weeksof training.

Dependent Variable	Group	Pre-test Mean ± SD	Post-test Mean ± SD	Sig.
Weight (Kg)	Tababta	84.99 ± 4.96	81.45 ± 4.91	*0.034
	Cinnamon	82.18 ± 3.91	79.92 ± 3.12	*0.046
	Tabata + Cinnamon	78.28 ± 4.98	72.54 ± 4.9	*0.014
	Control	80.95 ± 3.66	81.67 ± 3.17	0.243
BMI (kg/m ²)	Tababta	26.9 ± 1.57	25.8 ± 1.55	*0.034
	Cinnamon	26.0 ± 1.24	25.3 ± 0.99	*0.046
	Tabata + Cinnamon	24.8 ± 1.58	22.9 ± 1.55	*0.014
	Control	25.6 ± 1.16	25.8 ± 1.00	0.243
Combat readiness point	Tababta	429.6 ± 6.71	466.8 ± 12.8	0.053
	Cinnamon	467.8 ± 33.3	496.4 ± 25.28	0.051
	Tabata + Cinnamon	433.6 ± 19.7	497.2 ± 19.2	*0.001
	Control	480.6 ± 40.37	474 ± 39.85	0.533
VO ₂ max (ml/kg/min)	Tababta	44.91 ± 5.22	50.34 ± 4.46	*0.003
	Cinnamon	45.36 ± 5.39	47.72 ± 4.96	*0.011
	Tabata + Cinnamon	44.23 ± 5.02	51.96 ± 5.64	*0.001
	Control	47.16 ± 4.45	47.69 ± 5.63	0.243
Blood lactate (mmol/L)	Tababta	11.7 ± 0.26	10.40 ± 0.38	*0.02
	Cinnamon	11.93 ± 0.48	11.53 ± 0.38	0.051
	Tabata + Cinnamon	11.80 ± 0.29	9.87 ± 0.52	*0.001
	Control	12.02 ± 0.27	11.95 ± 0.24	0.543

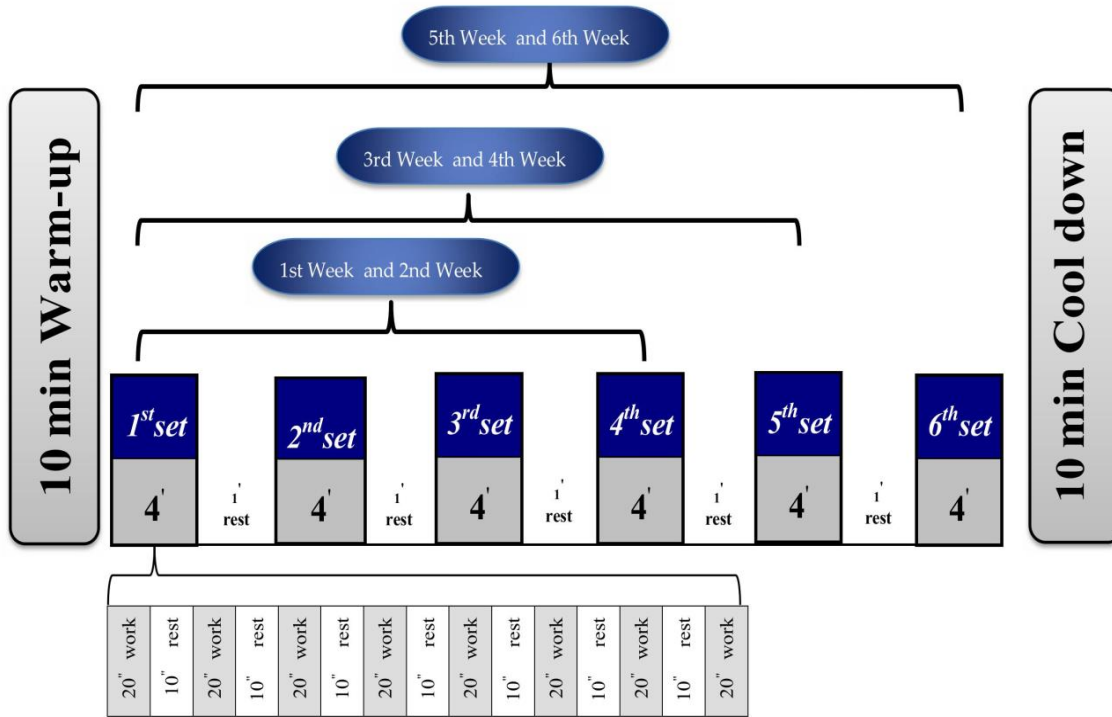


Figure 1. Tabata functional training protocols. This chart shows the schedule of Tabata functional training, which is the high-intensity interval training style that is still used in military cadets. It has three stages: 1. Warm-up (10 min); Light cardiovascular prep and mobility; Injury prevention and Joint readiness. 2. Main Set (30-40 min) - 8 rounds x 4 min/set using 20 sec exercise + 10 sec rest intervals; Aimed intensity: 87-100 % HRmax with a view to targeting both anaerobic and aerobic adaptation - Movements involve non weighted and functional to military relevant training exercises (e.g. walking lunges, Burpee, Bicycle crunches, Inchworm to Push-ups to Opposite Toe Touch, Triceps Dips, Mike Tyson push-ups 3. Cool-down (10 min); Passive recovery and stretch to increase circulation and normalize heart rate back to normal.

Table 2. Results of ANCOVA Analysis between groups

Dependent Variable		Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Combat readiness point	Between groups	5942.738	3	1980.913	38.294	.000*	.833
	within groups	1189.783	41	51.730			
Blood lactate (mmol/L)	Between groups	6.560	3	2.187	20.190	.000*	.725
	within groups	2.491	41	.108			
Vo ₂ max (ml/kg/min)	Between groups	130.104	3	43.368	8.036	.001*	.512
	within groups	124.126	41	5.397			

* p < 0.01 in comparison to baseline value

Descriptive statistics including mean and standard deviation and inferential statistics were applied after the collection and refinement of the raw data. During the inferential statistics section, based on the level of measurement of the data, the Shapiro-Wilks test was conducted to verify the normal distribution of the data, the dependent t -test was conducted to compare the changes between the averages of each group before and after the study, and the analysis of covariance test was conducted to compare the groups. When the difference between groups was significant, a paired comparison was conducted with the Bonferroni post hoc test. Data analysis in this study was conducted using the SPSS version 25 statistical program at the $p= 0.05$ level of significance.

Results

Table 1 shows the values of anthropological and physiological parameters at the baseline, and the values at the end of the 6-week training. Baseline Characteristics. The study was done with all the 40 participants. No significant differences were observed in the four groups of the study at baseline in terms of age, height, weight, BMI, VO₂max, blood lactate, or combat readiness scores ($p>0.05$).

Within-group comparisons (pre- vs. post-test)

It was also found that, after six weeks of intercession, Tabata training (T), cinnamon supplementation (S) and Tabata+ cinnamon (TS) showed considerable differences with baseline values. Control group (C) did not experience any significant changes (Table 1).

Body weight and BMI

Weight also reduced significantly in the T group (3.54 kg, $p=0.034$), in the S group (2.26 kg, $p=0.046$) and in the TS group (5.74 kg, $p=0.014$). BMI also fell significantly in all the three groups of interventions (largest fall in the TS group, -1.9 kg/m^2 , $p=0.014$).

Combat readiness score

All of the intervention groups showed a great improvement in combat readiness scores.

T group: +37.2 points ($p=0.053$), S group: +28.6 points ($p=0.051$), TS group: +63.6 points ($p=0.001$). The control group (non-significantly reduced) was -6.6 points ($p=0.533$). The combat readiness score is shown in Figure 2.

VO₂max (Cardiorespiratory fitness)

The VO₂max in T group increased by +5.43 mL/kg/min ($p=0.003$), in S group increased by +2.36 mL/kg/min ($p=0.011$), in TS group increased by +7.73 mL/kg/min ($p=0.001$). No significant difference of VO₂max was detected in the control group ($p=0.243$).

Blood lactate concentration

The most considerable changes were observed in all intervention groups: T group: -1.3 mmol/L ($p=0.02$), S group: -0.4 mmol/L ($p=0.051$), TS group: -1.93 mmol/L ($p=0.001$). The control group was not changed ($p=0.543$). The blood lactate concentration is shown in Figure 2.

Between-group comparisons (ANCOVA)

ANCOVA analysis confirmed significant differences between groups for all outcome variables ($p<0.001$), with large effect sizes (Partial Eta Squared >0.5 in all cases) (Table 2).

The TS group demonstrated significantly superior improvements compared to both T and S groups across all primary outcomes (Table 2).

Discussion

Cinnamon supplementation and combat readiness.

Combat readiness is a complex concept which includes physical fitness, mental alertness, emotional stability and performing under stress. To military personnel, and indeed to military personnel in high-intensity operations, optimal readiness is not only an aspiration, but a matter of life and death. Training and deployment of soldiers is extremely demanding, and can include repeated anaerobic exercise, sleep deprivation, caloric limitation,

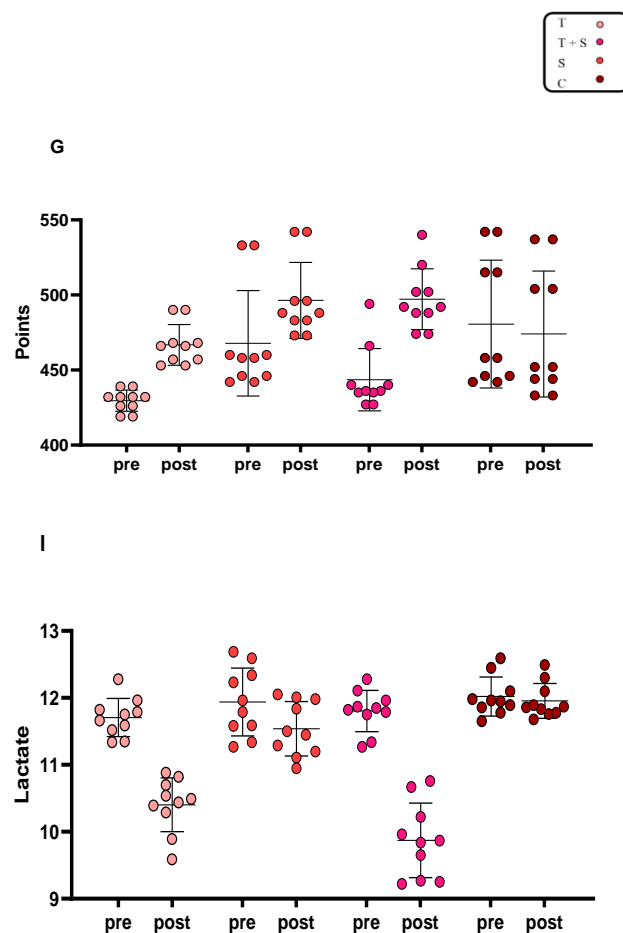


Figure 2. Changes in combat readiness points and lactate concentration across four intervention groups (Control, Tabata training, Cinnamon supplementation, and combined Tabata+Cinnamon) before and after a 6-week intervention. Significant improvements were observed in the Tabata and combined groups, particularly in combat readiness points and lactate concentration groups ($p<0.001$). These results support the implications of synergistic effects of high-intensity functional exercise and cinnamon supplement on combat readiness points and lactate concentration. error bars represent standard deviation, T, Tabata Training; T+S, Tabata Training+Cinnamon supplementation; S, Cinnamon supplementation; and C, Control.

and psychological stress. In this regard, any nutritional interventions that may improve recovery, limit fatigue and promote long-term performance are of deep concern. The results of the research indicate that cinnamon supplementation in the combination with Tabata-style high-intensity interval training (HIIT) may be important to increase combat readiness of young male cadets. This improvement was reflected in elevated VO₂max scores, reduced post-exercise blood lactate levels, and enhanced combat performance indices. The results are in concurrence with earlier studies that show cinnamon contains bioactive compounds that have the ability to regulate main physiological routes of energy metabolism, inflammation and oxidative stress (Shang et al.,2021; Tuzcu et al.,2017).

Cinnamon is rich in phytochemicals; it also contains phytochemicals like cinnamaldehyde, eugenol and other polyphenols which have anti-oxidant and anti-inflammatory properties (Pagliari et al., 2023). These compounds were also reported to increase insulin sensitivity, enhance skeletal muscle glucose uptake and reduce indicators of systemic inflammatory processes that have been directly correlated to performance and recovery (Anderson et al., 2009; Qin et al., 2003; Guo et al., 2024). The effects of cinnamon may enhance endurance and reduce fatigue, particularly in military training contexts where rapid mobilization and energy recovery are critical, cinnamon effects raise blood glucose levels to normal, and lower oxidant injury.

In addition, cinnamon has also shown some potential to have a vasodilatory effect that would have proven effective in improving the supply of oxygen to the working muscles during high-intensity exercise (Yanaga et al., 2006). Holistically augmented vascularity augments the vascular effectiveness not merely to enhance aerobic capacity, but to also get rid of exhaustive metabolic wastes such as lactate, hence reducing the sensation of muscular fatigue, as well as decreasing the time to recuperation. These physiological benefits are most beneficial on a battlefield, since the army is exposed to hard physical activities that are overworked without a lot of room to rest.

Combat readiness encompasses psychological and cognitive traits, such as mental resilience, focus, and decision-making capacity

To be combat ready, physical capacity is not all that is required because the human mind must also be in a state of sharpness and control. We hypothesized that chronic inflammation and oxidative stress would be involved in cognitive decline and influence mood swings and impair decision making and response time during stressful events (Dantzer et al., 2008). The neuroprotective benefits of Cinnamon including its capacity to modulate neuroinflammation signaling and aid in the drainage of synapses can offer further beneficial effects to maintain mental acuity during protracted surgical operations (Angelopoulou et al., 2021).

Although the precise impact of cinnamon on mood and stress regulation remains under investigation, preliminary trials have shown promising effects. Cinnamon can reduce the psychological impact of rigorous training and combat stress; thereby, rendering preparation holistic in nature (Sohrabi et al., 2017).

Military applications on nutrition

One of the most interesting characteristics of the intervention is the ease of accessibility of cinnamon as the nutritional interventi-

-on. In comparison with synthetic supplement or pharmacological agents, cinnamon is available readily, culturally acceptable and inexpensive. Its introduction into dietary intake of military rations or as part of a daily supplementation regimen would only require slight adjustment in the logistical process and would, therefore, be a viable strategy that can be scaled up. The safety profile of cinnamon is on a positive side too. There were no side effects recorded in this trial and other studies demonstrated that it could be effectively used even with a higher dose (Gu et al., 2022). This leaves cinnamon as a relatively safe and highly beneficial intervention, one that could be applied to a large proportion of military populations with minimal concern of contraindicating effects or side effects related to the intervention.

The change in blood lactate dynamics with cinnamon supplementation

Blood lactate is not a sole biochemical parameter; the physiological side of the question is how the body responds to stress, intensity and recovery. In military populations where bodily exercise is normally highly distressing and occasionally prolonged, elevated blood lactate concentrations could be a pointer of the stage at which ideal physical effort turns to fatigue. Agility in controlling the accumulation of lactic acid and accelerating its escape therefore emerges as a topic of discussion about the working readiness and fitness during stress. Cinnamon supplementation lead to significant reduction in lactate in post exercise blood samples during tabata-style high-intensity interval training (HIIT) in cadets. Particularly, this is notable as the conditions that occur during HIIT typically necessitate the glycolytic systems to be running at full capacity with the generation of significant amounts of lactate. The described reduction in lactate concentrations indicate that cinnamon has certain regulatory effects on the energy balance due to buffering effects against the physiological stressor of high-intensity exercise (Sabzevari Rad et al., 2025).

Lactate- a twin-edged mark in performance

Lactate is often misunderstood as merely a byproduct of anaerobic metabolism, whereas in reality, it serves both as a metabolic signal and a fuel source. In the absence of oxygen to the muscles due to the restriction characteristic in the exercise at high intensity, lactate is generated by the dismantling of pyruvate in order to maintain the production of ATP. Over accumulation of lactate can cause acidosis and impair the contractile ability of the muscles and recovery (Brooks et al., 2020). Military service men who must repeat the hard-work and minimal rest intervals, must possess good lactate clearance.

The decrease in the amount of blood lactate in the group that received supplementation with cinnamon could be explained by an increase in mitochondrial effectiveness and effective lactate

shuttle mechanisms. The bioactive constituents of cinnamon, specifically cinnamaldehyde and polyphenols, have been demonstrated to induce expression of oxidative phosphorylation and glucose metabolism enzymes which may assist with the shift between anaerobic and aerobic energy production systems (Hashimoto et al., 2008).

The effects of cinnamon on the glycolytic flux and lactate clearance

In both human and animal trials, cinnamon has been shown to boost glucose uptake and usage in skeletal muscles, therefore reducing the effect of insulin. Cinnamon can reduce the need for anaerobic glycolysis during exercise by lowering lactate production capacity, hence boosting insulin signaling, therefore minimizing the need for anaerobic glycolysis during exercise. Furthermore, cinnamon's antioxidant properties may maintain mitochondrial integrity, therefore enhancing Cori cycle and lactate oxidation (Shen et al., 2014).

A study conducted by Mang et al (2006) used the consumption of cinnamon extract that increased the factors related to metabolic syndrome, and this directly relates to lactate metabolism during exercise. In a similar study, Qin et al. established that glucose uptake in adipocytes was improved by cinnamon, and once again this was an indication that overall energy metabolism was increased leading to a decrease in lactates during high intensity activities (Mang et al., 2006).

Anti-inflammatory and vascular properties

Cinnamon may also have anti-inflammatory and vasodilatory properties as a contributor to a greater lactate clearance. Damaged circulation and inflammation can hamper lactate walking and slow its extraction through the muscle. Cinnamon also helps reduce pro-inflammatory cytokines and improves endothelial functioning that can help lactate move faster to the liver and the heart where it could be more efficiently metabolized (Schink et al., 2018).

It also enhanced vascular perfusion to enhance oxygen delivery as this plays a major role in aerobic metabolism and lactate oxidation. Cinnamon can increase the synthesis of nitric oxide and lower vascular resistance, which may aid in maintaining optimal blood flow throughout and after exercise to speed up recovery and minimize the burden of lactic accumulation on the testing person (Bahri et al., 2022).

Implications to tactical populations

The military personalities are affected by the implications of these finding very far. Reduction in lactates in blood leads to decreased muscular fatigue, increased recovery and sustained performance in different training or combat training events. Cinnamon is amo-

-ng the simplest and naturally occurring interventions to adopt in set ups that lack rest and work incessantly as it could enhance metabolic endurance.

Cinnamon has an overall access and safety position that makes it the best candidate of applying cinnamon to military nutrition. Unlike the synthetic ergogenic aids, cinnamon is both culturally acceptable and cheap without any side effects when consumed in moderation. Its addition to the typical ration or supplementation programs would likely represent a scalable intervention as compared with the work needed to improve lactate management and functionalities among tactical units.

VO₂max with cinnamon supplementation augmentation

The most generally recognized standard of measurement of the aerobic capacity and cardiovascular fitness is O₂ maximal oxygen uptake (VO₂max). VO₂max is not only a performance measure in tactical populations like the military but a survival, mission performance, and long-term health resiliency measure. The ability to experience a high-intensity physical activity, a fast recovery and be metabolically efficient because of the stress has a direct relationship with VO₂max. As a result, the science of military training and nutrition treats interventions that increase VO₂max safely and effectively as of strategic value.

In this study, Tabata-type high-intensity interval training (HIIT) in conjunction with cinnamon supplement resulted in a statistically significant difference in VO₂max in young male cadets. This fact becomes even more important considering the shortness of the intervention period (six weeks) and the simplicity of the nutritional strategy selected. The measured improvements should reflect the fact that cinnamon has physiological impacts on oxygen consumption, mitochondrial efficiency and cardiovascular dynamics, all of which are key factors with regard to the stimulation of VO₂max.

Biological constitution of cinnamon together with cardiovascular regulation

Cinnamon (*Cinnamomum* spp.) extracts have a wide range of bioactive compounds, such as cinnamaldehyde, coumarin, eugenol, and polyphenols that have been demonstrated to alter cardiovascular and metabolic systems (Shang et al., 2021). The compounds show antioxidant, anti-inflammatory, and vasodilatory effects which may provide a beneficial oxygen delivery effect and utilization during exercise.

Recent evidence indicates that cinnamon may exert positive effects on the alterations in endothelial functions associated with the increasing nitric oxide (NO) bioavailability and a decrease in vascular resistance and increase in the blood flow to working muscles. Increased perfusion promotes the transportation and uptake of oxygen due to which higher VO₂max is supported. In

addition, cinnamon also seems to stabilize oxidative stress, which is likely to preserve mitochondrial integrity permitting more effective aerobic metabolism and ATP generation during prolonged exertion (Schink et al., 2018).

Mitochondrial efficiency and oxygen utilization

VO₂max is in essence an index of the mitochondrial capacity to burn oxygen and produce energy. The polyphenolic concentrations in Cinnamon have been demonstrated to enhance the products of genes in the mitochondrial biogenesis procedure and oxidative phosphorylation, such as PGC-1 α and cytochrome c oxidase (Wood dos Santos et al., 2018). Cinnamon may also improve the efficiency of the body to take up oxygen when exercising hard by increasing the level of mitochondrial density and functioning. In a recent, randomized trial published by Sabzevari rad et al, cinnamon supplementation was linked to better markers of aerobic metabolism, as well as the improved markers of oxidative damage in physically active adults (Sabzevari rad et al., 2024). Such findings are congruent with the findings of the current study and indicate a wider applicability of cinnamon as functional food to improve aerobic performance.

Anti-inflammatory and recovery

Inflammation has been shown to limit VO₂max improvement, especially in individuals who undergo long-term physical stress. The effects of cinnamon on tissue inflammation and repair processes outlined above (by inhibition of NF- κ B and pro-inflammatory cytokines such as IL-6 and TNF- α) could improve recovery and minimize the adverse systemic impact of training (Pagliari et al., 2023; Khedkar et al., 2023). Quicker recovery makes it possible to train more often and more intensively, and such an effect has the potential to drive higher VO₂max over time. Moreover, the ability of cinnamon to provide glycemic regulation can also offer increased energy levels on an endurance-based activity. Cinnamon stimulates insulin sensitivity and glucose uptake thus, regulating the continuous supply of fuel to working muscles and increase the delivery of fuel to working muscles whilst reducing premature fatigue and facilitating continued aerobic performance (Bahri et al., 2022).

Contributions to the military readiness and performance

It is not applicable to the military members, as VO₂max is not an abstract value, it is an operating parameter that defines operating capacity. VO₂max values guarantee less endurance and recovery time, more risk of injury. The cost advantage of the addition of cinnamon to military dietary regimens is acceptable, and the practice is culturally correct and represents a physiologically workable means of enhancing aerobic capacity. Cinnamon has minimal threat about possible side effects and could easily be used in meal plans or with meal-time supplements. This

spaciousness and richness of usefulness, in its impact on heart-of-the-blood, mitochondrial-priming, etc.-is a contrivance singularly useful in the endeavor after the maximization of performance.

Cinnamon–exercise synergy and organ crosstalk mechanisms

During high-intensity interval training, muscles let out signaling proteins like IL-6 and irisin, which tweak how the liver releases glucose while calming body-wide inflammation (Pedersen & Febbraio, 2012). Instead of just stacking effects, cinnamon's active parts mainly cinnamaldehyde and polyphenols boost the liver's response to insulin and lower oxidative damage, possibly boosting the signals kicked off by physical activity (Dehghan et al., 2025). Because of this two-way link between muscle and liver, people doing both exercise and cinnamon intake cleared lactate faster, alongside better VO₂max numbers. Cinnamon might help balance immune reactions after workouts less neutrophil and monocyte activity, yet lymphocytes keep working (Moradi Talgerd et al., 2023). Because it tones down inflammation, recovery could speed up, keeping tactical teams sharper between missions. When physical stress ramps up immune activity, cinnamon steps in with calming effects, showing how muscles and immunity influence each other on a practical level. Overall, this data hints that cinnamon might do more than just boost metabolism - it could help organs "talk" to each other when under heavy exercise strain or recovering from it. Coming research ought to include biological signals tied to organ interaction, like substances released by liver or muscle cells, along with immune markers, in order to figure out how these combined benefits actually work.

Limitations

While this study provides valuable insights into the synergistic effects of cinnamon supplementation and Tabata-style high-intensity interval training (HIIT) on performance and metabolic outcomes in tactical populations, several limitations should be acknowledged.

Firstly, the sample size of 48 cadets, though adequate for this study, limits the ability to generalize the findings to larger or more diverse populations. Future studies should aim to include a broader sample, incorporating a range of demographics such as different age groups, genders, and fitness levels, to assess the applicability of these results across various populations.

Secondly, the duration of the intervention (six weeks) may not have been sufficient to fully capture the long-term effects of cinnamon supplementation on performance and metabolic health. Given the short-term nature of this study, the observed benefits may be transient. Longitudinal studies with extended intervention periods are needed to assess the chronic effects of cinnamon supplementation in combination with high-intensity training.

Another limitation is the absence of a placebo control group, which could have introduced potential biases. The psychological impact of knowing that participants are receiving a performance-enhancing supplement may have affected the outcomes, leading to a placebo effect. Future research should include a placebo control to better isolate the true effects of cinnamon supplementation and account for psychological factors.

Moreover, this study did not measure biochemical markers such as inflammatory cytokines, oxidative stress markers, or insulin sensitivity, which could provide a deeper understanding of the physiological mechanisms through which cinnamon exerts its effects. Including these markers in future studies would offer a more comprehensive view of the metabolic pathways involved.

Additionally, the psychological factors such as motivation, sleep, and stress, which could significantly influence physical performance, were not controlled in this study. These factors are particularly relevant in military populations, where mental resilience plays a crucial role in performance. Future research should control for these variables to obtain more accurate results.

Furthermore, this study was conducted exclusively on young male military cadets, which limits the generalizability of the findings to other populations. Female participants, older adults, and individuals with varying fitness levels may respond differently to cinnamon supplementation. Future studies should include more diverse participant groups to evaluate the broader applicability of cinnamon as a functional food in various populations.

A key limitation of the present study is the absence of a placebo control group. Although the intervention arms were compared against a non-intervention control, the lack of a placebo condition restricts our ability to fully disentangle the physiological effects of cinnamon supplementation from potential expectancy or psychological influences. Participants in the supplementation group were aware that they were receiving an active compound, which may have contributed to perceived or behavioral changes independent of its metabolic impact. Future research should therefore adopt a placebo-controlled design to strengthen causal inference and to more clearly isolate the specific ergogenic contributions of cinnamon from possible placebo responses.

Finally, while this study measured $VO_2\text{max}$ and blood lactate concentration as primary indicators of performance and metabolic health, these markers may not fully capture all aspects of an individual's metabolic capacity. Additional assessments of mitochondrial function, glucose metabolism, and other physiological variables should be included in future studies to provide a more holistic understanding of cinnamon's effects on performance.

Conclusion

The present study demonstrates that supplementation with cinnamon (*Cinnamomum* spp.), a time-honored medicinal spice widely recognized in traditional medicine systems, can meaningfully enhance the physiological adaptations to high-intensity training. When combined with Tabata-style HIIT, cinnamon improved aerobic capacity ($VO_2\text{max}$), reduced post-exercise blood lactate levels, and elevated combat readiness among young military cadets. These findings suggest that cinnamon may serve as a natural, safe, and cost-effective ergogenic aid that bridges the principles of traditional medicine and modern exercise science. From a traditional medicine perspective, cinnamon's phytochemicals—such as cinnamaldehyde, eugenol, and polyphenols—likely act through antioxidant, anti-inflammatory, and metabolic pathways that support resilience, endurance, and faster recovery. Integrating such herbal agents into performance nutrition aligns with the holistic philosophy of traditional medicine, which emphasizes balance, adaptation, and natural restoration of body function under stress.

This study therefore provides translational evidence for the inclusion of traditional herbal interventions in contemporary performance optimization strategies, particularly for tactical or military populations exposed to high physical and psychological demands. Future research should investigate the molecular mechanisms underlying these effects, evaluate standardized cinnamon formulations, and explore applications across diverse populations and training contexts. Ultimately, cinnamon emerges not only as a culinary spice but as a functional traditional remedy with tangible value in modern performance and metabolic health enhancement.

What is already known on this subject?

- Cinnamon (*Cinnamomum* spp.) is a traditional medicinal spice with well-documented, antioxidant, anti-inflammatory, and insulin-sensitizing properties.
- Previous studies have demonstrated the metabolic benefits of cinnamon supplementation, including improved oxidative stress markers, glucose regulation, lipid profiles, and in both healthy and clinical populations.
- High-intensity interval training (HIIT), particularly the Tabata protocol, is a time-effective and efficient method to enhance aerobic and anaerobic performance, especially in tactical and military populations.
- Military cadets, often face high physical and psychological demands that can lead to inflammation, oxidative stress, and impaired recovery.

- Despite the individual benefits of cinnamon and HIIT, their combined effects on combat readiness, physical performance, and metabolic health have not been thoroughly investigated in military settings.

What this study adds?

- This is the first randomized controlled trial to investigate the combined effects of cinnamon supplementation and Tabata-style high-intensity interval training on performance and metabolic outcomes in tactical cadets.
- The study demonstrates that cinnamon supplementation significantly boosts the physiological benefits of HIIT, including greater improvements in reduced post-exercise blood lactate levels, VO_{2max} , and superior gains in combat readiness scores.
- Findings support the integration of traditional herbal medicine with modern exercise protocols as a safe, feasible, and culturally appropriate strategy to optimize recovery and physical performance in military populations.
- The results provide translational evidence for cinnamon as a functional ergogenic aid that may improve lactate clearance, resilience, and energy metabolism, under high-intensity physical stress.
- This study introduces a scalable intervention, novel, and low-cost with potential applications in military training, sports performance, and occupational health settings.

Organ Cross-Talk Tips:

- The combination improved lactate clearance, suggesting enhanced communication between working muscles (producing lactate) and the liver (clearing it).
- The intervention enhanced overall combat readiness, indicating a positive multi-organ response involving the metabolic, cardiovascular, and neuromuscular systems.

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Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Compliance with ethical standards

Conflict of interest The authors declare that there is no conflict of interest in the present research.

Ethical approval This study was approved by the Research Ethics Committee of Islamic Azad University, Ardabil Branch, on 3 March 2025 (Approval Code: IR.IAU.ARDABIL.REC.1403.229). All procedures involving human participants were conducted in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments.

Informed consent All participants were fully informed about the study objectives, procedures, potential risks, and benefits. Written informed consent was obtained from each participant prior to enrollment, and participants were informed that they could withdraw at any stage without penalty. The authors affirm that participants gave informed consent for the publication of anonymized data derived from this study. No personally identifiable information is included in this manuscript.

Author contributions

Conceptualization: R.S.R., M.S.K., Methodology: R.S.R., M.S.K., Software: R.S.R., M.S.K., Validation: R.S.R., M.S.K.; Formal analysis: R.S.R., M.S.K.; Investigation: R.S.R., M.S.K.; Resources: R.S.R., M.S.K.; Data curation: R.S.R., M.S.K.; Writing - original draft: R.S.R., M.S.K.; Writing—review & editing: R.S.R., M.S.K.; Visualization: R.S.R., M.S.K.; Supervision: R.S.R.; Project administration: M.S.K.; Funding acquisition: R.S.R.

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