Short Communication

Compact food bar improves cardiopulmonary function in men military athletes: A randomized, placebo-controlled, single-blind clinical trial

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Background: This study aimed to evaluate the effects of compact food bar (CFB) designed on cardiopulmonary function in men athletes who serve in military service. **Materials and Methods:** In this randomized, single-blind, controlled clinical trial, 46 men of military staff were arranged into 2 groups and studied for 28 days; one branch used 3 packs daily, 700 kcal each, of CFB with Functional compounds (Caffeine and L-arginine) and the other group used regular food during training course. Maximal oxygen uptake (VO_2 Max) *in vitro* with cardiopulmonary exercise test, body composition, and physical activity were assessed and recorded at baseline and end of the study period. **Results:** VO_2 Max ($P = 0.05$) significantly increased in CFB group compared with baseline. Moreover, VO_2 Max ($P = 0.01$), VO_2/HR ($P = 0.04$), oxygen uptake/heart rate (VO_2/HR) ($P = 0.03$), and ventilation per minute/oxygen uptake (VE/VO_2) ($P = 0.03$) significantly increased in CFB group compared with control group. In comparison, there was no significant difference in mean ventilation per minute/carbon dioxide production (VE/VCO_2) ($P = 0.41$), ventilation per minute (VE) ($P = 0.69$), and breathing frequency ($P = 0.056$). No significant effect of CFB was found on weight, body mass index ($P = 0.23$), lean body mass ($P = 0.91$), and body fat mass ($P = 0.91$). **Conclusion:** Our results show that intervention with CFB is more effective than regular diet in improving cardiopulmonary function in men athletes who serve in military service.

Key words: Athlete, cardiorespiratory function, compact food bar

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INTRODUCTION

Physical fitness, as a necessity for any athlete, includes physical health, the ability to perform exercises continuously and skillfully, the ability to return to normal after high pressure, and confidence in dealing with any situation for a military person.[1]

Proper nutrition is one of the most important aspects of health and plays a decisive role in the level of physical fitness and mental performance of individuals, especially military personnel.[2] The physical needs of the individuals during times of crisis and military operations, which are accompanied by stress or short or long-term pressures, are completely different from normal living conditions. Also, these psychological and physical stresses, which are different and more complex, determine nutritional needs when combined with harsh environmental conditions.[3] It has now become clear that proper selection of carbohydrates, proteins, and fluids, as well as their intake timing, may affect athletic performance.[4]

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In addition to the effect of the type and level of macronutrients and fluids, functional compounds such as caffeine, vitamins and minerals, probiotics, beta-alanine, arginine, and creatine could also affect performance.[5,6] Functional foods contain special compounds that have not only nutritional and energy-providing features but also have well-established and proven health-promoting, preventive, and disease-reducing properties.[6-8] Clinical studies have highlighted that the use of beta-alanine supplements for at least 4 weeks increases athletic performance and reduces the time it takes to reach maximal oxygen uptake (VO_2 Max) fatigue.[9-11]

In critical situations, food choices are limited, and the comparative diets available replace compact food bar (CFB) during missions.[2] CFB is part of the diet that is used in times of crisis, maneuvers, and military missions.[12,13] These foods are durable and ready to eat. Also, they have low volume and weight, which is significant regarding that a soldier can carry his or her diet easily.[14,15] In addition to athletes and military personnel, CFB can be used in times of crisis and treatment for humanitarian purposes.[13] One of the criteria for evaluating physical fitness performance is cardiac and pulmonary endurance, which can be measured by the cardiopulmonary exercise test (CPET). CPET predicts the ability of cardiac and pulmonary function by measuring the parameters of VO_2 Max, carbon dioxide production (VCO_2), ventilation per minute (VE), ventilation per minute/oxygen uptake (VE/VO_2), ventilation per minute/carbon dioxide production (VE/VCO_2), and oxygen uptake/heart rate (VO_2/HR).[16]

The efficiency of the ventilation and oxygen transmission system is of great importance in improving cardiac and pulmonary readiness.[17] It has been reported that some supernatural food compounds increase VO_2 Max, but not the amount of oxygen delivered to the tissue per minute.[18-21] VO_2 Max is one of the indicators that is highly correlated with aerobic performance.[22] Increased cardiac and pulmonary endurance could lead to an increase in the amount of VCO_2 and increased VE.[23] Increased lactic acid stimulates the respiratory center and increases VE, leading to an increase in the VE/VO_2 ratio, indicating the onset of the anaerobic phase.[24] The ratio of ventilated air volume to the amount of VE/VCO_2 also shows the efficiency of the respiratory system. Moreover, the decrease in this ratio indicates an increase in cardiac and pulmonary efficiency in energy generation from the aerobic pathway and delayed anaerobic stage.[25]

Despite several works on the effect of functional food on improving performance and physical fitness,[26-29] few studies have examined a CFB with functional food such as caffeine and L-arginine to evaluate cardiac and pulmonary endurance.[30] This study aimed to investigate the effect of consuming CFB on the cardiac and pulmonary endurance of the military personnel compared to the control group.

MATERIALS AND METHODS

Participants and eligibility screening

Participants were recruited from military athletes of the Tehran military army in January 2020. Criteria for entering the study included age range of 20–45 years, no use of antioxidant and herbal supplements since at least 1-month before the start of the study, no history of any allergies to certain compounds, and no use of tobacco. Also, the participants with known metabolic disorders including coronary heart disease, diabetes mellitus, hyper- or hypothyroidism, renal disease, liver disorders, inflammatory diseases, taking antioxidant, anti-inflammatory, or multivitamin supplements within the past 12 weeks, therapy with medications, adherence to a special diet or weight loss program last 12 weeks were excluded.

Study design

This study was designed as a randomized, single-blind, placebo-controlled clinical trial with two parallel groups over a 28-day period. Participants took part in this study after learning about the objectives and methods of conducting the study, and their willingness to cooperate was confirmed by them signing the written consent form. This study was approved by the ethics committee of the Isfahan University of Medical Sciences, Isfahan, Iran. This clinical trial is currently registered on the Clinical Trials Registration, coded as IRCTID: IRCT20121216011763N43.

A total of 90 athletes were evaluated for inclusion criteria; 54 of them met participation eligibility of the study and 8 refused to participate in the study. The remaining 46 participants were assigned to two groups randomly: an intervention group (23 participants) receiving a CFB with functional food and a control group (23 participants) receiving a regular food used in military training courses intervention for 28 days. A simple randomization method was used to assign the participants in two groups in accordance with computers-generated unique codes [Figure 1]. Since our study is a pilot study, we did not find similar studies. Therefore, for calculation of sample size, we used the following formula, where standard deviation, β (type two error), and confidence interval were 0/18, 0/05, and 95%, respectively. We needed 23 participants for each group.

$$M = (ZS/D)^2$$

Each athlete received a diet (~2800–3200 kcal) according to RMR and based on the Mifflin-St Jeor equation. This diet was adjusted for their physical activity. The macronutrient composition of the diet was approximately 50%–55% carbohydrates, 20% protein, and 30% fat. However, the nutritionist designed the requirement of energy and distribution of macronutrients and provided special dietary recommendations based on AHA guidelines.[31]

The intervention group received 3 CFBs each day (with every CFB being 125 g and 700 kcal) for 10 days. Three CFBs provided 2100 kcal energy needed daily, and the rest of the energy requirement was supplied from foods including bread, cheese, nuts, and dried fruit o provide the required daily energy daily. The control group received a regular diet (the same calories as the intervention group) that was cooked in a military kitchen. The conditions for performing the activities in terms of some variables such as temperature, humidity, sports coverage, sleep, type of sports, and caloric activities were the same for all samples. Test measurements were performed for all participants from 7:15 to 9 o'clock.

Diet formulation features

In this study, to produce CFBs, several ingredients were used: corn and whole-grain soybean flour purchased from Ilia Factories, Kermanshah, Iran, and Toos Soyan, Mashhad, Iran, respectively; milk protein concentrate (MPC) (Golshad, Mashhad, Iran) to supply protein; cocoa butter substitute (Cargill, Kuala Lumpur, Malaysia) as a source of lipid' granule form of (Iran sugar Co., Tehran, Iran) as a source of simple sugars; lecithin (amphiphilic ingredient thus great emulsifier) and polyglycerol polyricinoleate (provided from Nestlé Iran, Co., Tehran, Iran); cocoa powder (Delfi Cocoa, Johor Darul Takzim, Malaysia); and formulated vitamins and minerals blend (Osve Iran Pharm, Inc. Tehran, Iran) to meet the IOM requirements for EFPs [Table 1]. The CFBs output data for carbohydrate, fat, and protein are shown in Table 2.

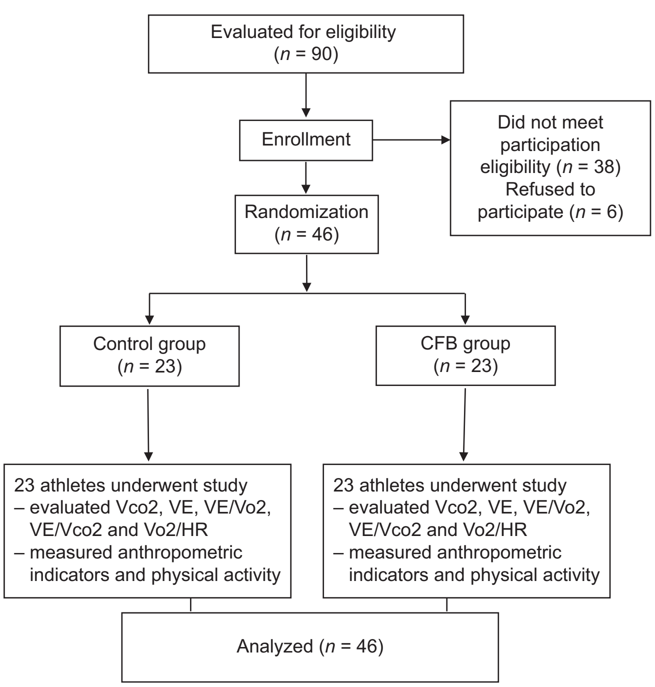

Figure 1: Flowchart shows the study design

This study aims to investigate the effect of consuming CFB with functional compounds (caffeine and L-arginine) on the cardiac and pulmonary endurance of the military personnel compared to the control group. Energy-consuming exercises were designed for volunteers who needed to be fed by appropriate ratios of macronutrients such as carbohydrates, fats, and proteins. However, the type of macronutrients was taken into account precisely to promote physical performance outcomes. For example, casein and arginine were used as the protein and amino acid for MPC and soybean, respectively. Multivitamins, minerals, L-arginine (1 gr/2100 kcal), and caffeine (500 mg/2100 kcal), in addition to the CFBs, guaranteed adequate energy supply, enhanced immune system, reduced oxidative stress, and finally increased functional capacity.

Table 1: Energy values, amounts of macronutrients, micronutrients, and functional compounds used in the military diet based on the recommended dietary allowance

Nutritious	Amounts
Energy (kcal/day)	2100
Carbohydrates (g/day)	230
Protein (g/day)	70
Fat (g/day)	100
Vitamin A (unit/day)	900
Vitamin C (mg/day)	60
Vitamin D (unit/day)	200
Vitamin E (unit/day)	15
Vitamin K (µg/day)	120
Thiamine (mg/day)	1.2
Thiamine (mg/day)	1.3
Niacin (mg/day)	16
Vitamin B6 (mg/day)	1.7
Folic acid (µg/day)	400
Vitamin B12 (µg/day)	2.4
Biotin (microgram/day)	30
Pantothenic acid (mg/day)	5
Calcium (mg/day)	1200
Iron (mg/day)	8
Phosphorus (mg/day)	700
Iodine (µg/day)	150
Magnesium (mg/day)	400
Zinc (mg/day)	11
Selenium (µg/day)	50
Copper (µg/day)	60
Manganese (mg/day)	2.3
Chromium (µg/day)	30
Potassium (mg/day)	4700
Sodium (mg/day)	1500

Test measurements

In this study, cardio-respiratory endurance was evaluated using the laboratory method by the respiratory gas analyzer (ergospirometry or CPET). For this purpose, a MetaLyzer 3B model by the German Cortex Biophysik Co. was utilized to directly evaluate maximum oxygen consumption (ml/kg/min), VCO_2, VE, VE/VO_2, VE/VCO_2, and VO_2/HR. The measurement of anthropometric indicators was performed by the Bioelectrical Impedance Analysis device (In Body S10 model, made in South Korea).

Statistical analysis

The normalization and the distribution of the data were evaluated using the Kolmogorov–Smirnov test. The independent *t*-test was used to calculate intergroup changes. The paired *t*-test was used to evaluate intragroup changes before and after the intervention. Each of the variables was reported as a mean ± standard deviation. Analysis of covariance was used to compare the mean values of the tests between the two groups at the end of the study after modifying the distortion variables, including age and height. $P < 0.05$ was considered significant in all tests. All data were analyzed using the SPSS software version 20 (IBM SPSS Statistics, Armonk, USA).

RESULTS

The results of the Kolmogorov–Smirnov test revealed the normal distribution of data in the intervention and control groups. There is no statistically significant difference between the two groups in terms of baseline characteristics including age, body mass index (BMI), height, weight, level of physical activity, and energy and protein intake ($P > 0/05$) [Table 3]. As it is shown in Table 4, changes in weight, BMI, body fat percentage, and fat mass were not significant in each group and between group at the end of study ($P > 0.05$).

As shown in Figure 2, there was statistically significant in VO_2 Max, VE/VO_2, and VO_2/HR in the CFB group pared with the control group during the 28-day intervention period ($P < 0.05$). Meanwhile, there was no significant difference observed in the average VE/VCO_2, VE, and breathing frequency (BF) ($P > 0.05$) [Table 5].

DISCUSSION

To the best of our knowledge, this study is the first randomized, double-blind placebo-controlled clinical trial designed to assess the effect of CFB on cardiopulmonary endurance in military athletes. One of the major findings of the present paper is that consuming a CFB improved the increase in cardiorespiratory endurance based on the measurement of VO_2 Max, VE/VO_2, and VO_2/HR in the intervention group compared to the control group. Meanwhile, there was no significant difference in the average weight, BMI, body fat mass body fat mass (BFM), and lean body mass (LBM) in the intervention group compared to the control group before and after the study.

The results of this study, consistent with those of Entezari *et al.*,[32] showed an increase in VO_2 Max in the intervention group compared to the control group at the end of the study.

Table 2: Values and shares of energy from macronutrients in 100 g of the military diet

Macronutrients	Amounts (g)	Share of energy
Total carbohydrate	58.59	45% of total energy
Complex carbohydrates	40.71	70% of total carbohydrate energy
Corn flour	34.9	
Soy flour	5.81	
Simple carbohydrates	18.88	30% of total carbohydrate energy
Sugar	14.97	
MPC	2.91	
Fat	24.97	42% of total energy
CBS	21.03	
Corn and soy flour	3.86	
Protein	16.27	13% of total energy
MPC	8.14	
Soy flour	8.13	

MPC=Milk protein concentrate; CBS=Cocoa butter substitute

Table 3: General characteristics of individuals at the beginning of the study

Features	CFB‡‡ (*n*=23)	Control‡ (*n*=23)	*P*
Age (year)	23.95±3.23	24.18±2.9	0.44
Height (cm)	176.35±7.38	175.55±6.78	0.57
Weight (kg)	72.91±16.32	73.82±14.02	0.78
BMI (kg/m^2)	24.01±4.53	23.35±4.02	0.83
Energy (kcal)	2338.65±341.28	2359.45±362.02	0.84
Protein (g)	83.04±8.13	81.05±13.18	0.48

‡Receiver of CFB (military ration) during the 28 days of study; ‡‡Receiver of regular food during the 28 days of study; *P* value based on independent *t*-test; Values in terms of mean±SD. SD=Standard deviation; BMI=Body mass index; CFB=Compact food bar

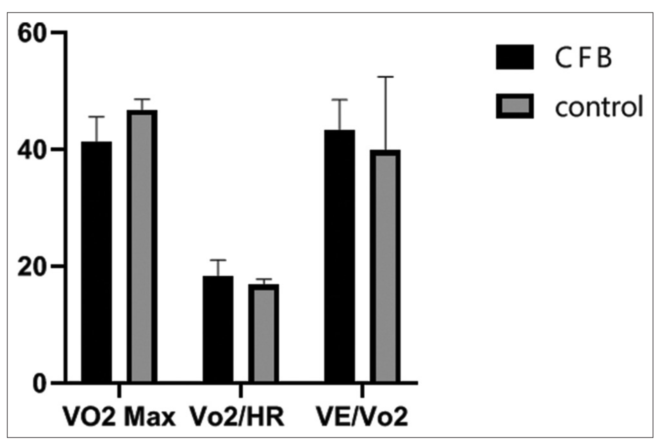

Figure 2: Mean ± standard deviation of VO_2 Max, VO_2/HR and VE/VO_2 at baseline and day 28 in compact food bar and control groups

Table 4: Anthropometric indicators and physical activity at the beginning and end of the study in the intervention and control group

Variables	Time	CFB‡‡ (*n*=23)	Control‡ (*n*=23)	*P*
Weight (kg)	Before intervention	72.91±16.32	73.82±14.02	0.83*
	After intervention	72.74±15.17	73.6±14.23	0.38**
	*P****	0.81	0.61	
	Percentage	0.23	0.29	
BMI (kg/m²)	Before intervention	24.01±4.53	23.35±4.02	0.57*
	After intervention	23.91±3.7	23.57±3.85	0.23**
	*P****	0.26	0.36	
	Percentage	0.40	−0.94	
BFM (%)	Before intervention	18.14±6.97	19.78±7.67	0.39*
	After intervention	18.08±7.22	19.52±7.44	0.91**
	*P****	0.63	0.12	
	Percentage	−3.47	1.31	
LBM (%)	Before intervention	58.83±9.97	58.32±6.06	0.70*
	After intervention	58.86±9.62	58.68±6.91	0.91**
	*P****	0.55	0.19	
	Percentage	−0.05	−0.61	
PA (km/day)	Before intervention	22.501±0.39	22.486±0.33	0.42*
	After intervention	22.401±0.31	22.389±0.29	0.61**
	*P****	0.39	0.37	
	Percentage	0.44	0.44	
Energy (kcal)	Before intervention	2889.82±364.32	2742.68±471.49†	0.21*
	After intervention	2894.82±548.17	2692.41±523.30	0.90**
	*P****	0.76	0.89	
	Percentage	−0.17	−1.82	

*Based on one-way ANOVA. **Adjusted based on covariance analysis; ***Paired *t*-test; ‡Receiver of CFB (military ration) during the 28 days of study; ‡‡Receiver of regular food during the 28 days of study; *P* value based on independent *t*-test; Values in terms of mean±SD. BFM=Body fat mass; LBM=Lean body mass; PA=Physical activity; CFB=Compact food bar; SD=Standard deviation; BMI=Body mass index

One study indicated that the 5 mg/kg dosage of caffeine increased the strength and speed of exercise.[23] Another study found that caffeine consumption on a bicycle test increased the exhaustion time and VO_2 Max.[33] Another study demonstrated that caffeine consumption at a dose of 5 mg/kg increased athletic performance and VO_2 Max.[25] In a study by Steven *et al.*, the use of arginine amino acids enabled the improvement of muscle mass and performance during exercise.[34] In one study, 2 g/day of L-arginine supplementation in men for 15 days reduced fatigue and increased VO_2 Max. In another study, L-arginine for 42 days at a dose of 2 g/day improved athletic performance in male athletes,[32,35] which was in line with our study.

In the present study, the daily intake of CFB significantly improved the ratio of VE/VO_2. In several studies, the ratio of VE/VO_2 has been measured as one of the indicators of respiratory efficiency.[4,35] Also, the mean changes in the VE/VO_2 ratio decreased after 28 days of intervention in the functional diet compared to the control group, i.e., the intervention improved lung function, while no significant difference was observed in VE/VCO_2.[17] The difference in research results between VE/VCO_2 and VE/VO_2 ratios can be explained by the fact that VE/VCO_2 has less variability than VE/VO_2.[17]

The findings of this study on VE/VCO_2 are inconsistent with the results of Farrell *et al.*,[15] probably due to the incremental test type used in cardio and pulmonary testing. The results of our intervention revealed that 28 days of supplementation with CFB improved the VO_2/HR ratio. In this regard, the higher the amount of oxygen in the body between two consecutive heartbeats is, the more effective the cardio-respiratory system will be in delivering oxygen to the active muscles.[35] According to the present study, the intervention has a significant effect on this ratio. These findings are consistent with the results of research by Habedank *et al.*[17]

It seems that CFB with functional food such as arginine, multivitamins-minerals, and caffeine could be effective in boosting athletic power by increasing the delivery of oxygen to the active muscles and subsequently increasing the oxygen uptake in the active muscles.[30,36] The role of arginine in nitric oxide endothelial synthesis could be regarded among the possible mechanisms of the functional compounds used in the military diet to improve and increase oxygen delivery capacity. This capacity, in turn, is a measure of improving aerobic capacity, cardiorespiratory endurance, and functional capacity. Nitric oxide is a vasodilator that increases blood flow

Table 5: Indicators of cardiac and pulmonary endurance at the beginning and end of the study in the intervention and control groups

Variables	Time	CFB‡‡ (*n*=23)	Control‡ (*n*=23)	*P*
VO_2 Max (ml/min/kg)	Before intervention	40.6±3.32	41.7±2.16	0.41*
	After intervention	41.4±4.17	46.73±1.87	0.01**
	*P****	0.05	0.02	
	Percentage change	0.49	−0.07	
VO_2/HR (ml)	Before intervention	17.80±2.65	15.27±0.88	0.27*
	After intervention	18.27±2.78	16.85±0.94	0.04**
	*P****	0.131	0.008	
	Percentage change	−2.64	10.34	
VE/VO_2	Before intervention	42.4±6.01	42.14±4.13	0.39*
	After intervention	43.2±5.31	39.84±12.59	0.03**
	*P****	0.81	0.02	
	Percentage change	−1.88	5.45	
VE/VCO_2	Before intervention	36.8±3.03	37.32±2.44	0.70*
	After intervention	36.6±2.74	37.41±3.51	0.41**
	*P****	0.646	0.917	
	Percentage change	0.54	−0.24	
VE (Lit/min)	Before intervention	93.9±14.50	98.78±0.84	0.14*
	After intervention	96.9±19.46	100.7±0.51	0.69**
	*P****	0.315	0.071	
	Percentage change	−3.19	−1.94	
BF (breaths/min)	Before intervention	43.2±3.90	41.33±0.82	0.95*
	After intervention	43.7±2.78	42.00±0.78	0.056**
	*P****	0.068	0.072	
	Percentage change	−1.15	−1.62	

*Based on one-way ANOVA. **Adjusted based on covariance analysis; ***Paired *t*-test; ‡Receiver of CFB (military ration) during the 28 days of study; ‡‡Receiver of regular food during the 28 days of study; *P* value based on independent *t*-test; Values in terms of mean±SD. VO_2=Oxygen uptake; VO_2 Max=Maximal oxygen uptake; HR=Heart rate; VE=Ventilation per min; VCO_2=Carbon dioxide production; BF=Breathing frequency; CFB=Compact food bar; SD=Standard deviation

to tissues during exercise, leading to increased oxygen delivery and oxygen uptake into the active muscles.[37] Therefore, improving the aerobic capacity of skeletal muscles enhances the oxidative capacity of skeletal muscle and produces more ATP in the Krebs cycle path by improving peripheral blood flow and muscular aerobic energy and using fatty acids as a sustainable energy source.[37]

Caffeine might be responsible for other possible mechanisms of the effect of a compact diet. Caffeine increases energy consumption, stimulates the release of fatty acids from adipose tissue,[36,38] boosts and regenerates energy sources faster, delays the fatigue threshold (possibly by preventing acid-base imbalance and reducing glycolysis and lactic acid accumulation in the muscles), and subsequently reduces the VE/VO_2 ratio.[25] Caffeine is a potentiating factor affecting the release of catecholamines and also cell protection against cell damage due to its antioxidant effects.[36] Caffeine can improve endurance and physical function in long-term activities with submaximal intensity. Moreover, it can be effective in prolonging the fatigue reaching time by storing glycogen from increased lipolysis and consuming fatty acids as an energy supplier.[30,38]

To the best of our knowledge, this study is the first that assessed the effect of consuming CFB on the cardiac and pulmonary endurance of athletes. Despite the advantages of this research, it also suffered from some limitations. First, the sample size was small and participants of the study were restricted to athlete men. Hence, this could limit the generalizability of results. Second, the duration of intervention in this study was short. Therefore, further studies are warranted to confirm these results. Third, we could not evaluate biochemical indices including serum level of ghrelin, leptin, and NPY due to financial constraints and available facilities.

CONCLUSION

This study indicated that consuming a nutritional supplement (i.e., CFB) with functional food in military athletes in difficult conditions and intense activity has positive effects on improving cardiac and pulmonary endurance. However, no significant effects were observed on BMI and body composition indices.

Ethical statement

All protocols were approved by the Iranian Registry of Clinical Trials (IRCT). Also, all participants gave written informed consent to participate in this study.

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Conflicts of interest

There are no conflicts of interest

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