

Research Article

Comparative effects of high-intensity functional and multimodal training on physical fitness and cardiometabolic adaptations in military officer cadets

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Abstract

High-intensity training is recognized as a time-efficient method for simultaneously improving physical fitness and metabolic health, but direct comparisons between high-intensity functional training (HIFT) and high-intensity multimodal training (HIMT) are limited, especially in military officer cadets. The aim of the present study was to compare the effects of high-intensity functional and multimodal training on physical fitness and cardiometabolic adaptations in military officer cadets. In this two-arm interventional study with a pre-test/post-test design and no non-exercise control group, 28 male students of Imam Ali (AS) University were randomly allocated to two groups of 14 each (HIFT and HIMT) and trained for eight weeks. Lipid profile (TC, LDL, HDL, and TG), cardiorespiratory fitness (VO₂max), power (Sargent jump), and agility (Illinois Agility Test) were measured before and after the course. Data were analyzed using a mixed ANOVA at a significance level of 0.05. The main effect of time was significant for most variables; in both groups, VO₂max, power, and agility improved and total cholesterol (TC) and triglyceride (TG) decreased while HDL increased ($p < 0.001$). LDL changes, despite a decreasing trend, did not reach significance ($p = 0.071$). No significant group $\times$ time interaction was found for any variable, indicating no significant differences between the two methods. Both HIFT and HIMT were associated with improvements in the physical fitness and lipid profile of military students to a similar extent over eight weeks. Therefore, either method can be used as an effective and time-efficient strategy for improving combat readiness and metabolic health, based on available facilities and conditions.

Key Words: High-intensity functional training, High-intensity multimodal training, Lipid profile, Physical fitness, Military officer cadets

Introduction

Physical fitness is a fundamental component of military performance, as the nature of military missions requires high levels of cardiorespiratory endurance, strength, power, and desirable body composition. As future officers, cadets at military colleges are in a critical period of physical and professional preparation, and improving their physical fitness affects not only operational performance but also long-term health and combat readiness (Haddock et al., 2016). However, concerns have been raised about the efficacy of traditional military physical-training programs which have focused primarily on running and aerobic endurance and researchers have shifted toward more efficient, multidimensional training methods (Poston et al., 2016). Along with functional indices, lipid profile is recognized as one of the most important markers of cardiovascular health. Dyslipidemia is defined as increased total cholesterol (TC), low-density lipoprotein (LDL-C), and triglyceride (TG), and/or decreased high-density lipoprotein (HDL-C), and is an established risk factor for cardiovascular disease (CVD) (Hedayatnia et al., 2020). In atherosclerosis, modified LDL particles are deposited in the inner layer of the arterial wall and initiate atherogenesis; therefore, undesirable levels of these indices are associated with an increased risk of cardiovascular events (Hedayatnia et al., 2020). A sedentary lifestyle combined with inappropriate nutritional patterns can exacerbate these risk factors; in contrast, regular physical activity is considered one of the most effective non-pharmacological strategies to reduce this risk through favorable adjustment of the lipid profile, and meta-analytic evidence shows that exercise, especially high-intensity exercise, can improve blood-lipid indices (Wood et al., 2019). In recent years, high-intensity interval training (HIIT) has received widespread attention due to its time-saving nature and effectiveness in improving metabolic and fitness indicators. Meta-analytic evidence suggests that HIIT is at least as effective as moderate-intensity continuous training (MICT) in improving lipid profiles while requiring less time (Wood et al., 2019). In this regard, two emerging training approaches high-intensity functional training (HIFT) and high-intensity multimodal training (HIMT) have received attention.

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High-intensity functional training (HIFT) is a program that combines high-intensity, high-variance, multi-joint functional movements to simultaneously improve overall fitness, including cardiorespiratory endurance, strength, power, and body composition (Feito et al., 2018). Programs aligned with HIFT principles—such as CrossFit and the U.S. Marine Corps High-Intensity Tactical Training (HITT) program have become increasingly popular in military populations and are considered a viable option for combat readiness because they promote "general physical fitness" rather than focusing solely on aerobic endurance (Haddock et al., 2016). High-intensity multimodal training (HIMT) is a term introduced by Sharp et al. (2022) to encompass a broader range of combined aerobic, resistance, and/or bodyweight training performed at high intensities (Sharp et al., 2022). This method combines aerobic and resistance training in a single session, providing a time-efficient pattern, and has been shown to have positive effects on aerobic fitness, muscular strength, and health indices (Sharp et al., 2024). In the research literature, HIMT is sometimes used as an umbrella term that also includes HIFT; however, in practice, the two can be operationalized as distinguishable protocols based on the emphasis on the type of movements (functional/CrossFit movements in HIFT versus structured aerobic-resistance combinations in HIMT).

Despite the growing evidence of the beneficial effects of these methods, studies directly comparing HIMT and HIFT on lipid profiles and physical-fitness factors especially in the specific population of military officer cadets are very limited, and methodological heterogeneity in existing studies has made accurate comparison difficult (Sharp et al., 2022). Therefore, the present study was designed to compare the effects of the two training methods, HIMT and HIFT, on the lipid profiles and selected physical-fitness factors of military university students, to provide empirical evidence to inform the selection of the most effective training method for improving the health and fitness of this population. To our knowledge, no previous study has directly compared HIFT and HIMT in military officer cadets while simultaneously evaluating physical fitness and cardiometabolic outcomes.

Materials and Methods

Participants

The current research was applied in nature, using a two-group pre-test/post-test design with two independent training groups (HIFT and HIMT) and no non-exercise control group. The statistical population consisted of students of Imam Ali (AS) University. The required sample size was calculated using G*Power software, based on an effect size of 0.4, a power of 0.95 (two groups and two measurements), and an alpha level of 0.05,

yielding 28 participants. Given a 15% anticipated dropout, 37 eligible volunteers were enrolled at the beginning of the study. Following baseline testing, the 37 volunteers were randomly allocated to the HIFT or HIMT group using a computer-generated random-number sequence. During the eight-week intervention, nine participants withdrew, leaving 28 ($n=14$ per group) who completed the study and were analyzed. Because the study included two active training arms without a non-exercise control group, it is best described as a two-arm randomized comparison rather than a fully controlled trial.

Of the 37 volunteers initially enrolled, 9 (24%) did not complete the study. Reasons for withdrawal were musculoskeletal injury unrelated to training ($n=2$), scheduling or operational conflicts ($n=4$), and voluntary withdrawal ($n=3$); no withdrawal was attributable to an exercise-induced injury or adverse event. To assess potential attrition bias, baseline characteristics (age, height, body mass, BMI, and baseline fitness) of the 9 non-completers were compared with those of the 28 completers using independent-samples t-tests, and no significant differences were found (all $p>0.05$), indicating that dropout was unlikely to have introduced meaningful selection bias. The final analyzable sample ($n=28$; 14 per group) matched the a priori target derived from the power analysis.

Before the study, students were provided with an informed-consent form, a personal-information questionnaire (age, height, weight, sports history), and a health questionnaire, and their eligibility to participate in the exercise program was confirmed.

Measurements

All research variables including lipid profile, body-fat percentage, power, agility, and cardiorespiratory fitness were measured in two stages: before the start of the course (pre-test) and after eight weeks of training (post-test). To determine the lipid profile, blood sampling was performed after a 12-hour overnight fast between 7:00 and 9:00 a.m. Participants were advised to refrain from strenuous exercise for 48 hours prior to blood sampling. Five millilitres of venous blood were collected from the antecubital vein of each participant, and the samples were centrifuged for 10 minutes at 3000 rpm to separate the serum. The weight and standing height of each student were assessed with an accuracy of 0.1 kg and 0.1 cm, respectively, using a medical scale and stadiometer (Seca 284, Germany).

Physical-fitness assessment

Cardiorespiratory fitness (VO₂max). A 1.5-mile (2.4-km) run test was used to estimate maximal oxygen consumption. Participants ran 1.5 miles in the shortest possible time, and their running times were recorded. VO₂max ($\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) was estimated using the equation $\text{VO}_2\text{max} = (483 \div \text{running time in minutes}) + 3.5$

American College of Sports Medicine, ACSM's Guidelines for Exercise Testing and Prescription, 10th). The 1.5-mile run is a standard field test of aerobic capacity widely used in military and law-enforcement fitness assessments, and the present sample (young, college-aged males) falls within the population in which such field estimates perform well. This is a field-based estimate rather than a direct laboratory measurement, however, and estimated values are sensitive to pacing strategy, running economy, motivation, and environmental conditions. To minimize these sources of error, all tests were conducted on the same 400-m track, and pre- and post-tests were performed at the same time of day.

Agility. The Illinois Agility Test was used to measure agility. The track was 10 m long and 5 m wide, with four cones placed along the centre axis at equal intervals. The participant lay prone behind the starting line and, at the examiner's signal, completed the route at maximum speed with successive changes of direction. Time was recorded with a stopwatch, and the better of two attempts was used as the agility score.

Power. Lower-limb anaerobic power was assessed using the Sargent vertical-jump test. The participant's maximum standing reach height was recorded; the participant then jumped as high as possible without a step, using an explosive movement, and the highest point of reach was marked. The difference between the two values was recorded as the vertical-jump height, and the best of three attempts was selected. Lower-limb explosive power was calculated using the Sayers equation (Sayers et al., 1999): Peak power (W)=60.7×jump height (cm)+45.3×body mass (kg)–2055.

Heart-rate monitoring. Training intensity was prescribed as 85–90% of maximum heart rate (HRmax). HRmax was estimated using the age-predicted equation $HR_{max}=220-\text{age}$, and heart rate was monitored during sessions to ensure the target intensity was maintained.

Measurement of body-fat percentage

Body-fat percentage was measured using the three-site skinfold method with calipers between 8:00 and 10:00 a.m., according to the manufacturer's instructions. All measurements were taken on the right side of the body by a single examiner to reduce inter-individual error. In men, three sites were measured: chest, abdomen, and thigh. Each site was measured twice and the average recorded (a third measurement was taken if the difference was too great).

Training protocol of the HIFT group

The HIFT program consisted of functional movements using bodyweight and equipment. The protocol was implemented over eight weeks. Training intensity was kept constant throughout, wi-

-thin 85–90% of HRmax, the total duration of each session was 25–30 minutes, and the duration of each activity phase was constant at 30 seconds. Incremental overload was applied not by increasing intensity but by increasing training volume and density: the number of rounds increased from 2 in Week 1 to 5 in Week 8, and rest between rounds decreased from 60 to 15 seconds, so that the work-to-rest ratio changed from 1:2 to 2:1. Full details are given in Table 1. Movements (performed as a circuit each round): jumping jacks, squats, burpees, hip raises, battle ropes, squat jumps, Hindu push-ups, and alternating lunges.

Training protocol of the HIMT group

The HIMT group's training program consisted of a set of functional and aerobic-resistance movements, including running, bear crawl, stationary bike, barbell deadlift, rowing, step-up, thruster, and plank. This protocol was implemented over eight weeks, and the training intensity was kept constant throughout the period and in the range of 85 to 90% of maximum heart rate (HRmax), while the total duration of each session was between 25 and 30 minutes and the duration of each activity phase was constant and equal to 30 seconds. The incremental overload was applied not by increasing the intensity, but by increasing the volume and density of the training; The number of rounds gradually increased from 2 rounds in the first week to 5 rounds in the eighth week, and at the same time, the rest time between rounds decreased from 60 seconds to 15 seconds, so that the work-to-rest ratio changed from 1:2 to 2:1. Full details of intensity, duration, number of rounds, and rest time per week are listed in Table 2.

To manage accumulated fatigue, Week 5 was programmed as a planned reduced-volume (deload) week, in which the number of rounds was deliberately lowered before volume and density progressed to their peak in Week 8.

Statistical analysis

After collecting and screening the raw data, descriptive and inferential statistics were used. Descriptive statistics (mean and standard deviation) described participant characteristics and study variables. The normality of the distributions was examined using the Shapiro–Wilk test. A dependent (paired) t-test was used to compare within-group changes (pre- versus post-test means for each group). To simultaneously examine the effects of time (pre- versus post-test), group (HIFT versus HIMT), and their interaction, a 2 (group)×2 (time) mixed ANOVA was used. Effect sizes (partial η^2) and, where relevant, mean differences are reported alongside the F statistics, because partial η^2 is less sensitive to sample size and provides a more appropriate index of practical significance. All analyses were performed in SPSS version 26 at a significance level of $p=0.05$. Along with statistical

Table 1. Training Protocol of the HIFT.

Week	Intensity	Total Session Time	Work Time (sec)	Rest Time (sec)	Rounds	Functional Movements
1	85–90% HRmax	25–30 min	30	60	2	Jumping jacks
2	85–90% HRmax	25–30 min	30	45	3	Squat
3	85–90% HRmax	25–30 min	30	30	3	Burpee
4	85–90% HRmax	25–30 min	30	30	4	Hip Raise
5	85–90% HRmax	25–30 min	30	30	3	Battle Ropes
6	85–90% HRmax	25–30 min	30	15	4	Squat jump
7	85–90% HRmax	25–30 min	30	15	4	Hindu push-up
8	85–90% HRmax	25–30 min	30	15	5	Alternating Lunge

Table 2. Training Protocol of the HIMT

Week	Intensity	Total Session Time	Work Time (sec)	Rest Time (sec)	Rounds	Functional Movements
1	85–90% HRmax	25–30 min	30	60	2	Running
2	85–90% HRmax	25–30 min	30	45	3	Bear Crawl
3	85–90% HRmax	25–30 min	30	30	3	Stationary Bike
4	85–90% HRmax	25–30 min	30	30	4	Barbell Deadlift
5	85–90% HRmax	25–30 min	30	30	3	Rowing
6	85–90% HRmax	25–30 min	30	15	4	Step-up
7	85–90% HRmax	25–30 min	30	15	4	Thruster
8	85–90% HRmax	25–30 min	30	15	5	Plank

significance, effect sizes were computed for each analysis and are reported as partial eta squared (η^2) for the main and interaction effects of the mixed ANOVA. Partial η^2 values were judged as small (0.01), medium (0.06) or large (0.14) following Cohen's criteria.

Results

Table 3 shows the anthropometric and physiological parameters at the beginning and end of the eight-week training period. This study included 28 participants. At baseline, no statistically significant between-group differences were observed for age, height, weight, BMI, VO_{2max} , lipid profile, or physical-fitness indices (all $p>0.05$). The largest numerical difference was in HDL (HIFT 60.85 ± 2.81 vs. HIMT 62.85 ± 3.13 mg/dL), which did not reach statistical significance ($p=0.09$).

Training adherence and adverse events. The intervention comprised three supervised sessions per week over eight weeks (24 scheduled sessions in total). Mean attendance was $92.6\%\pm4.1$ in the HIFT group and $91.4\%\pm5.3$ in the HIMT group, corresponding to an average of 22.2 of 24 and 21.9 of 24 sessions completed per participant, respectively; all analyzed participants met the predefined minimum-attendance criterion of $\geq80\%$. No exercise-related injuries or adverse events occurred among the 28 participants who completed the study. No individual modifications to the prescribed protocol were required, and sessions were supervised throughout to ensure correct technique and adherence to the prescribed intensity.

Within-group comparisons (pre- versus post-test)

The paired t-tests showed that both HIFT and HIMT produced significant changes in all variables except LDL cholesterol after eight weeks ($p=0.001$), with LDL showing a non-significant decr-

-easing trend ($p = 0.071$).

Body composition (weight and BMI). A significant decrease was observed in both groups. HIFT weight decreased from 70.07 to 67.92 kg (≈2.15 kg) and HIMT from 69.21 to 66.92 kg (≈2.29 kg). Consequently, BMI decreased from 22.93 to 22.23 (HIFT) and from 21.78 to 21.06 kg/m² (HIMT), about a 3% decrease in both groups.

Cardiorespiratory fitness (VO_{2max}). The largest relative improvement occurred in this index. HIFT VO_{2max} increased from 42.24 to 46.63 (≈4.39 units, $\approx10.4\%$) and HIMT from 42.65 to 46.52 mL/kg/min (≈3.87 units, $\approx9.1\%$). Changes in VO_2 max are shown in Figure 1.

Lipid profile. Most of the lipid indices were significantly improved after 8 week training in both groups ($p=0.001$). The changes in the HIFT group were a decrease in TG $\approx9.4\%$ (Figure 5), TC

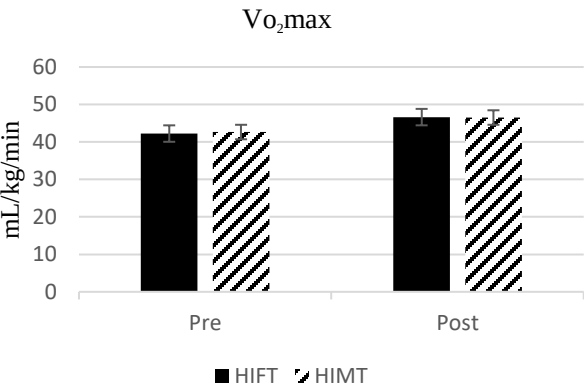


Figure 1. Estimated VO_{2max} (mL·kg⁻¹·min⁻¹) before and after eight weeks of training in the HIFT and HIMT groups. Bars are means; error bars are SD. * $p < 0.05$ versus pre-test.

Table 3. Selected anthropometric and physiological parameters at baseline and after 8 weeks of training.

Dependent Variable	Group	Pre-test Mean ± SD	Post-test Mean ± SD	Sig.
Weight (kg)	HIFT	70.07± 1.62	67.92 ± 1.35	*0.001
	HIMT	69.21± 1.16	66.92± 1.09	*0.001
BMI (kg/m²)	HIFT	22.93 ± 1.83	22.23 ± 1.48	*0.001
	HIMT	21.78 ± 1.32	21.06 ± 1.22	*0.001
VO2max (mL/kg/min)	HIFT	42.24 ± 1.14	46.63 ± 1.99	*0.001
	HIMT	42.65 ± 1.18	46.52 ± 2.10	*0.001
HDL (mg/dL)	HIFT	60.85± 2.81	63.64 ± 2.30	*0.001
	HIMT	62.85 ± 3.13	65.71± 3.29	*0.001
LDL (mg/dL)	HIFT	82.64 ± 8.67	78.92 ± 5.50	*0.001
	HIMT	83.78 ± 8.04	79.28 ± 6.89	*0.001
TC (mg/dL)	HIFT	167.92± 3.85	163.92± 9.91	*0.001
	HIMT	169.42± 10.91	164.71± 9.27	*0.001
TG (mg/dL)	HIFT	115.93 ± 4.10	105.07 ± 4.83	*0.001
	HIMT	115.36 ± 4.27	104.79 ± 4.53	*0.001
Illinois test (s)	HIFT	15.80 ± 0.29	14.51 ± 1.11	*0.001
	HIMT	15.87 ± 0.32	14.72 ± 0.74	*0.001
Power (W)	HIFT	4294.63 ± 281.06	4554.24 ± 289.14	*0.001
	HIMT	4275.83 ± 239.20	4538.14 ± 215.81	*0.001
Body fat (%)	HIFT	10.89 ± 1.19	10.29 ± 1.16	*0.001
	HIMT	11.36 ± 1.15	10.26 ± 1.14	*0.001
Vertical jump height (cm)	HIFT	52.54 ± 1.51	56.82 ± 1.22	*0.001
	HIMT	52.64 ± 1.60	56.96 ± 1.34	*0.001

* p < 0.05 in comparison to baseline value

≈2.4% (Figure 4), and an increase in HDL ≈4.6% (Figure 2); LDL decreased ≈4.5% (Figure 3) but was not significant. In HIMT group, the decrease in TG was about 9.2%, TC was about 2.8%, HDL was about 4.6% and LDL was about 5.4% (not significant). The highest reduction was of TG, which was seen in both groups.

Agility (Illinois test). Both groups reduced their running time, indicating improved agility (shorter time=better). HIFT time decreased from 15.80 to 14.51 s and HIMT from 15.87 to 14.72 s (≈1.2 s improvement in both groups) (Figure 6).

Power (Sargent jump). Lower-limb explosive power increased significantly in both groups. HIFT power increased from 4294.63 to 4554.24 W and HIMT from 4275.83 to 4538.14 W (≈260 W,

≈6%) (Figure 7). Vertical jump height increased significantly in both groups (HIFT: 52.54±1.51 → 56.82±1.22 cm; HIMT: 52.64 ±1.60 → 56.96±1.34 cm), consistent with the Sayers-derived increase in peak power reported above.

Body fat percent. Body-fat percentage also decreased significantly over time in both groups (main effect of time: F(1,26) =40.91, p<0.001, partial η²=0.611), from 10.89±1.19% to 10.29 ±1.16% in the HIFT group and from 11.36 ± 1.15% to 10.26± 1.14% in the HIMT group. There was no significant difference in the reduction in body fat between the two modalities, since the group×time interaction was not significant (F (1,26)=3.47, p= 0.074, partial η²=0.118). Changes in Body fat percent are shown in Figure 8.

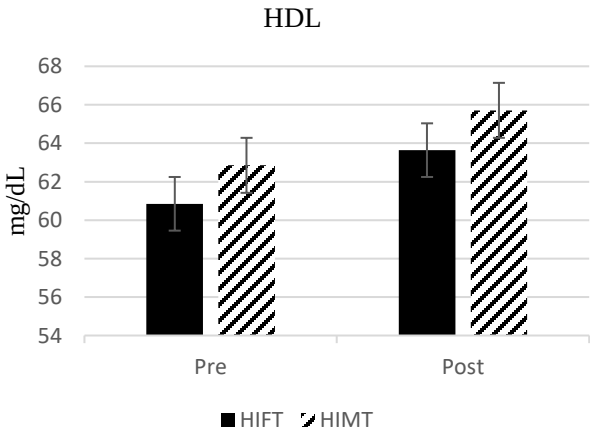


Figure 2. HDL-cholesterol (mg/dL) before and after the intervention in both groups. * p<0.05 versus pre-test.

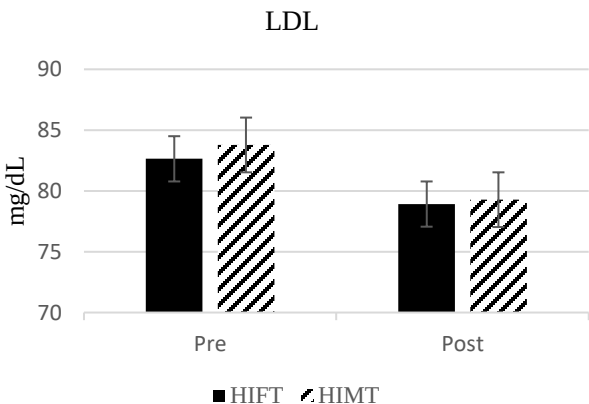


Figure 3. LDL-cholesterol (mg/dL) before and after the intervention. Within-group changes were not statistically significant (ns).

Table 4. Mixed-design ANOVA results (main effects of time and group, and group $\times$ time interaction) for the study variables.

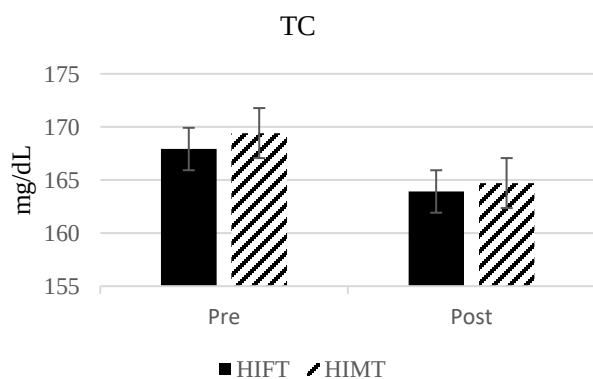
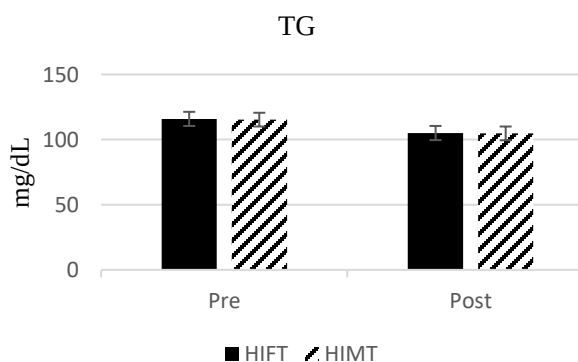
Dependent Variable	Source	Df	F	Sig.	PartialEta Squared
VO ₂ max	Time	1	158.95	<0.001*	0.859
	Group	1	0.08	0.782	0.003
	Group $\times$ Time	1	0.62	0.439	0.023
HDL	Time	1	60.20	<0.001*	0.698
	Group	1	4.30	0.048*	0.142
	Group $\times$ Time	1	0.04	0.851	0.001
LDL	Time	1	3.53	0.071	0.120
	Group	1	0.14	0.709	0.005
	Group $\times$ Time	1	0.03	0.859	0.001
TC	Time	1	114.36	<0.001*	0.815
	Group	1	0.09	0.764	0.004
	Group $\times$ Time	1	0.77	0.389	0.029
TG	Time	1	364.71	<0.001*	0.934
	Group	1	0.07	0.789	0.003
	Group $\times$ Time	1	0.06	0.801	0.003
Agility	Time	1	48.33	<0.001*	0.650
	Group	1	0.51	0.483	0.019
	Group $\times$ Time	1	0.16	0.690	0.006
Power	Time	1	672.21	<0.001*	0.964
	Group	1	0.03	0.861	0.001
	Group $\times$ Time	1	0.02	0.894	0.001
Body fat	Time	1	40.91	<0.001*	0.611
	Group	1	0.21	0.647	0.008
	Group $\times$ Time	1	3.47	0.074	0.118

Between-group comparisons (mixed ANOVA)

The mixed ANOVA showed that the main effect of time was significant for most variables: after eight weeks, in both groups, VO₂max, HDL, power, and agility improved and TC and TG decreased significantly ($p < 0.001$); only for LDL did the decrease fail to reach significance, showing a decreasing trend ($p = 0.071$). The group $\times$ time interaction was non-significant for all variables, indicating that the two modalities did not differ significantly in their effects on any outcome. The main effect of group was significant only for HDL ($p = 0.048$). This does not indicate the superiority of either modality. Because the group $\times$ time interaction for HDL was non-significant ($p = 0.851$), both groups increased HDL in parallel; HDL was simply higher in the H1MT group at both time points. Averaged across the two measurements, the between-

subjects analysis detected this small, stable offset with greater precision than the single baseline comparison, which did not reach significance. The main effect therefore reflects a pre-existing, non-significant baseline difference in HDL level that persisted across the study, rather than a differential response to training. Overall, both H1FT and H1MT were equally effective in improving physical-fitness indices and lipid profiles, with no significant difference between them (Table 4).

The main effect of time was associated with large effect sizes for all variables (partial η^2 ranging from 0.61 to 0.96): VO₂max ($\eta^2 = 0.859$), triglycerides (0.934), total cholesterol (0.815), HDL (0.698), agility (0.650), power (0.964), and body fat (0.611); LDL showed a small-to-medium effect (0.120). By contrast, the group $\times$ time interactions were negligible for all variables ($\eta^2 \leq 0.03$),

**Figure 4.** Total cholesterol (mg/dL) before and after the intervention in both groups. * $p < 0.05$ versus pre-test.**Figure 5.** Triglycerides (mg/dL) before and after the intervention in both groups. * $p < 0.05$ versus pre-test.

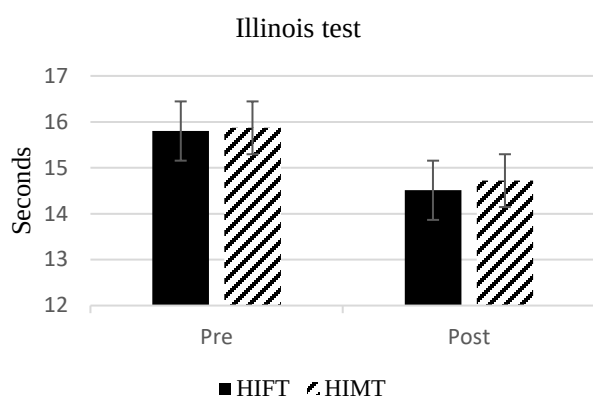


Figure 6. Illinois Agility Test time (s; lower is better) before and after the intervention in both groups. * $p < 0.05$ versus pre-test.

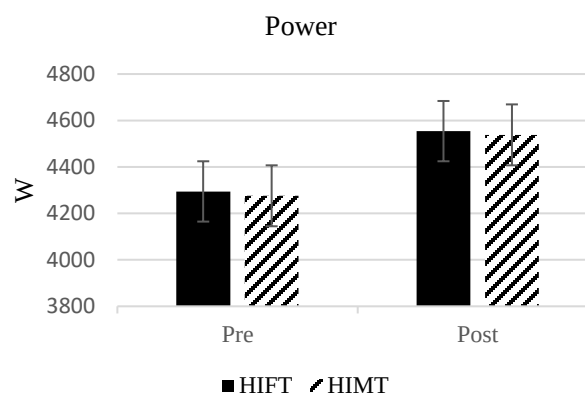


Figure 7. Lower-limb peak power (W; Sayers equation) before and after the intervention in both groups. * $p < 0.05$ versus pre-test.

and the between-group (main effect of group) effect sizes were also small ($\eta^2 \leq 0.14$), the largest being for HDL (0.142), consistent with the pre-existing baseline difference in HDL rather than a differential training response.

Discussion

This is the first study to directly compare HIFT and HIMT in military officer cadets while simultaneously evaluating physical fitness and cardiometabolic outcomes. Eight weeks of HIFT and HIMT were associated with significant improvements in most lipid-profile indices. In both groups, HDL increased and TC and TG decreased, while LDL did not decrease significantly. This pattern is consistent with existing evidence on the positive effect of regular physical activity on lipid metabolism. A systematic review by Mann et al. (2014) showed that exercise training, especially high-intensity, high-volume combined aerobic and resistance training, can produce the greatest improvement in lipid indices and reduce total cholesterol, the "gold standard" in cardiovascular prevention (Mann et al., 2014). Similarly, a network meta-analysis by Batrakoulis et al. (2022) confirmed that various types of exercise, including high-intensity functional training, have beneficial effects on cardiometabolic health and lipid profile (Batrakoulis et al., 2022). The increase in HDL and decrease in TG can be attributed to well-known mechanisms, including increased lipoprotein-lipase (LPL) activity, which accelerates triglyceride breakdown and reverse cholesterol transport, as well as increased fat oxidation and improved insulin sensitivity following high-intensity exercise. These mechanisms are consistent with Wang and Xu (2017), who reported that exercise improves lipid profiles by increasing LPL activity and accelerating triglyceride hydrolysis, and by reducing PCSK9 and improving reverse cholesterol transport; they also emphasized that HDL is the most sensitive marker to exercise, whereas significant reductions in LDL and TG usually require higher exercise intensity (Wang & Xu, 2017). This helps explain why TG,

the index most dependent on enzyme activity, showed the largest decrease ($\sim 9.3\%$) in the present study. The absence of a statistically significant reduction in LDL cholesterol, despite a consistent decreasing trend in both groups ($\sim 4.5\text{--}5.4\%$), is most plausibly explained by several interacting factors. First, LDL is well established as less responsive to exercise than HDL or triglycerides, typically requiring a higher exercise volume or a longer intervention to change significantly; Mann et al. (2014) explicitly noted that the LDL and TG response to exercise is heterogeneous and that significant LDL improvement often requires higher exercise volume or longer duration. Second, the eight-week duration may have been insufficient for LDL adaptations to reach significance. Third, the modest per-group sample ($n=14$) and the relatively large between-subject variability in LDL response—reflected in the small effect size for this variable (partial $\eta^2=0.12$) limited the statistical power to detect a change of this magnitude. A reduction of approximately 4–5% in LDL, although not statistically significant here, would be clinically meaningful if confirmed. There were no significant differences between the two methods in any lipid index, indicating

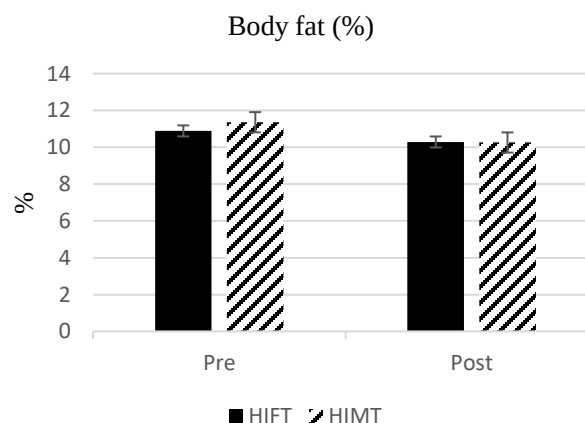


Figure 8. Body fat percent before and after the intervention in both groups. * $p < 0.05$ versus pre-test.

that both protocols, despite differing movement types, have similar efficacy in modifying the lipid profile, consistent with their common nature (high intensity and simultaneous engagement of the aerobic and muscular systems).

Eight weeks of training were associated with a significant increase in VO₂max in both groups (~9.7%), with no significant difference between HIFT and HIMT. This is consistent with existing evidence on the effectiveness of high-intensity training for cardiorespiratory fitness. Posnakidis et al. (2022) reported that eight weeks of HIFT in healthy active individuals significantly improved VO₂max (Posnakidis et al., 2022); Feito et al. (2018) reported an ~12% increase in VO₂max following HIFT programs, so the magnitude observed here is within the reported range (Feito et al., 2018). Importantly, the lack of a significant difference between modalities is supported by previous comparative studies. Menz et al. (2019) compared functional interval training with running and found both improved VO₂max to the same extent, with the "type of exercise" having no effect on cardiorespiratory adaptations (Menz et al., 2019). Cao et al. (2024) likewise showed that functional interval training and running produced similar VO₂max improvements (2.19 and 2.89 mL/kg/min, respectively; no significant difference) (Cao et al., 2024). This supports the view that exercise intensity, rather than the specific type of exercise, primarily determines aerobic adaptation; since both protocols were performed at high intensities, similar results would be expected. Physiologically, VO₂max improvements can be attributed to central adaptations (increased stroke volume and cardiac output) and peripheral adaptations (increased capillary density, mitochondrial number and function, and oxidative-enzyme activity in active muscle). High-intensity exercise provides a powerful stimulus for these adaptations, leading to significant cardiorespiratory improvements within a short period (eight weeks).

Eight weeks of training were associated with significantly increased lower-limb explosive power in both groups (~6%) and improved agility (a significant reduction in Illinois-test time), with no significant difference between HIFT and HIMT. For power, the findings are consistent with a meta-analysis by Wang et al. (2023) showing that HIFT has a significant (albeit small) effect on athletes' power (Wang et al., 2023), and with Posnakidis et al. (2022), who reported that eight weeks of HIFT significantly improved jumping performance (Posnakidis et al., 2022). This improvement can be attributed to neuromuscular adaptations, including increased motor-unit recruitment, improved intramuscular and intermuscular coordination, and adaptation to the multi-joint, explosive movements that both protocols emphasize.

For agility, the finding of significant improvement requires careful interpretation. Wang et al. (2023) reported that HIFT had no sign-

-ificant effect on agility in professional athletes; however, the same review cites studies in which agility improved in both experimental and control groups, with no significant difference between groups. The difference with our findings is likely due to the participants' fitness level: our cadets had not engaged in high-intensity exercise for at least six months before the intervention, and in such a lesser-trained population the capacity for agility improvement is greater, whereas professional athletes have less room for improvement. Physiologically, agility depends on power, speed, coordination, and neuromuscular control; because high-intensity training strengthens these components, improved agility can be expected (Wang et al., 2023). Finally, the lack of significant differences between the two methods in both power and agility can be attributed to their common nature: both use multi-joint, high-intensity movements that challenge the neuromuscular system similarly, resulting in similar adaptations.

Limitations

Several limitations should be acknowledged. The most important is the absence of a non-exercise control group. Although allocation to the two training arms was randomized, the study was uncontrolled; because both arms received an active intervention, we cannot fully rule out that part of the observed within-group changes reflects biological maturation, familiarization with the testing procedures (a test-retest or learning effect), or regression toward the mean rather than the training itself. This is particularly relevant for the field-based performance measures (1.5-mile run, Illinois Agility Test, and vertical jump), where a second attempt is commonly performed a few percent better through improved pacing and task familiarity. Reported systematic learning effects for such tests after familiarization are generally small (~1–3%; Moir et al., 2004), and the improvements observed for VO₂max (~9.7%) and triglycerides (~9.3%) exceed this range, whereas the changes in power (~6%) and agility (~7.8%) should still be interpreted with some caution. Importantly, the biochemical (lipid) outcomes are not subject to practice effects, so their significant, consistent changes in both groups support a genuine physiological response. Nevertheless, in the absence of a control group, the findings should be interpreted as associations rather than definitive causal effects. Second, although the completed sample (n=28) met the a priori power calculation, this calculation assumed a large effect size (f=0.40); the modest per-group size (n=14) therefore provides limited power to detect small or moderate between-group (group × time) differences, and the absence of significant interaction effects should not be taken as firm evidence that the two modalities are equivalent. Third, cardiorespiratory fitness was estimated from a field-based run test rather than measured directly (e.g., via gas analysis during a graded maximal test); although the 1.5-mile run is a validated and widely used field measure, direct laboratory assessment would provide a more precise estimate of VO_{2max} and is recommended for future studies. Fourth, the sample consisted exclusively of he-

-althy male military officer cadets from a single academy, which may limit generalizability to female personnel, older military populations, civilians, or individuals with different fitness levels. Fifth, the intervention lasted only eight weeks; a longer intervention may be needed to detect more pronounced changes in lipid fractions such as LDL and to evaluate the long-term sustainability of the adaptations. Sixth, dietary intake was not strictly controlled or monitored during the intervention. Although participants were instructed to maintain their usual eating habits, variations in nutritional intake cannot be excluded and may have influenced the metabolic outcomes (lipid profile and body-mass changes). Seventh, for the Illinois Agility Test the better of two attempts was recorded; while standard, this may be influenced by a within-session learning effect, and using the mean of the two attempts might have provided a more conservative estimate. Finally, the study focused on functional performance and conventional lipid variables without assessing additional mechanisms such as inflammatory biomarkers, oxidative stress, hormonal responses, or molecular indicators of adaptation; including these would provide a more comprehensive understanding. Future multicentre studies with larger and more diverse military populations, longer interventions, and follow-up assessments are warranted to confirm these findings.

Conclusion

The present study compared the effect of two training methods (HIFT and HIMT) on lipid profile and selected physical fitness parameters in the students of Imam Ali (AS) University. After 8 weeks of training both protocols were found to be significantly associated with an improvement in most indicators studied. In both groups VO₂max, explosive power and agility increased significantly, in the lipid profile the levels of HDL increased significantly while TC and TG decreased significantly; only LDL decreased although the change was not significant. The key finding was no significant differences between HIFT and HIMT in any of the variables, and no significant group×time interaction for any outcome. This indicates that both techniques, although different in terms of movement type and structure, are equally effective in enhancing physical fitness and cardiovascular health, which are both similar in nature (high-intensity multi-joint movements involving the aerobic and neuromuscular systems). From a practical point of view both methods are equally effective and one can choose which one is to be used depending on the facilities, equipment, training space and interest of the participants without fear of reduction of effectiveness. The flexibility is particularly important in officer academies when both approaches simultaneously enhanced multiple aspects of combat readiness (cardiorespiratory endurance, power, agility, and metabolic health) within a limited time frame (8 weeks), offering a time-efficient approach to enhancing operational readiness.

What is already known on this subject?

- High-intensity exercise, including high-intensity functional training (HIFT), is a time-efficient method for simultaneously improving multiple components of fitness and has gained popularity in military settings.
- Regular physical activity, particularly high-intensity exercise, can positively modify the lipid profile; increases in HDL and decreases in triglycerides are well-known adaptations, whereas the LDL response is more transient and often requires greater intensity or duration.
- The type of exercise (functional versus other modalities) does not usually affect the extent of cardiorespiratory-fitness improvement, which is primarily determined by exercise intensity.

What this study adds?

- HIFT and HIMT improved physical fitness and lipid profile in officer cadets to a similar extent over eight weeks, with no significant difference in effectiveness.
- This allows military planners to choose either method based on available facilities and conditions without concern about reduced effectiveness.

Organ Cross-Talk Tips:

- Increased LPL activity in muscle and liver, facilitating HDL-mediated cholesterol uptake from macrophages and arterial walls -demonstrating the muscle-liver axis in lipid regulation.

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Data availability

The data that support the findings of this study are available from the authors, but restrictions apply to their availability due to security and military considerations; they were used under license for the current study and are not publicly available. Data are available from the authors upon reasonable request and with the permission of Reza Sabzevari Rad.

Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

Ethical approval All procedures involving human participants were 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. No personally identifiable information is included in this manuscript.

Author contributions

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

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