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Effects of a Nine-Week Structured HIIT Program on VO_2max in First-Year Military Students: A Randomized Controlled Study

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Abstract
Physical fitness is a fundamental component of military readiness, with aerobic capacity representing a key determinant of operational performance. In military education settings, training time is often limited, which increases the need for efficient and targeted conditioning strategies. High-intensity interval training (HIIT) has been widely discussed as a time-efficient method capable of eliciting meaningful physiological adaptations. However, evidence regarding its specific effects on aerobic capacity in military populations remains inconsistent. Therefore, further evaluation of structured HIIT interventions under real-world military conditions is warranted. First-year military students ($n \approx 80–90$) were randomly assigned to either an intervention group completing a structured nine-week HIIT-based program or a control group following standard conventional physical training. The study was conducted across two consecutive measurement seasons using a randomized pre–post design. Aerobic capacity was assessed before and after the intervention using maximal oxygen uptake (VO_2max) determined via graded exercise testing. Both training programs were implemented within the regular physical training curriculum. The present study provides insight into the effects of a systematically designed HIIT intervention on aerobic capacity in a military student population. The findings contribute to a better understanding of how structured high-intensity training compares with conventional military physical training in terms of VO_2max adaptation. These results may help inform the development of efficient conditioning strategies within time-constrained military education environments. The study was conducted within a real-world military training setting, which may limit strict control over all external training influences. The duration of the intervention and the absence of intermediate physiological measurements may also have influenced the observed adaptations. Additionally, variability in sample size across measurement seasons should be considered when interpreting the findings.

KEY WORDS: *high-intensity interval training, HIIT, aerobic capacity, VO_2max, military training*

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1. Introduction

1.1 Military readiness and aerobic capacity

Military readiness requires a broad spectrum of physical and operational capabilities. Soldiers are expected to perform a wide range of demanding tasks, often under physically and mentally challenging conditions. Physical fitness therefore represents a fundamental component of overall readiness, with strength, speed, and endurance ideally developed in a balanced and well-level manner.

Military activities frequently include load carriage, material handling, digging, and prolonged movement with additional external loads typically ranging from 25 to 65 kg. These tasks are often performed in difficult terrain and environmental conditions. As a result, both muscular strength and aerobic capacity are essential for successful task performance during military operations and crisis situations [5].

Aerobic capacity, commonly expressed as maximal oxygen uptake (VO_2max), is considered a key indicator of physical performance and overall health. Higher VO_2max values are associated with improved endurance, better fatigue resistance, and more efficient recovery. A number of studies have reported a relationship between aerobic capacity and injury risk, suggesting that individuals with higher VO_2max may be less susceptible to musculoskeletal injuries [6, 7, 8]. Therefore, optimizing aerobic capacity represents an important objective within military training systems.

At the same time, military training programs must address multiple physical and technical requirements within limited time constraints. Traditional endurance-oriented approaches, typically based on continuous low- to moderate-intensity exercise, may not always provide the most efficient stimulus for overall physical development [4]. This has led to increasing interest in alternative training methods that are both time-efficient and physiologically effective. Based on a number of studies, high-intensity interval training (HIIT) appears to be a suitable method for improving physical fitness, including aerobic capacity [10, 9, 1]. Despite its importance, the development of VO_2max within time-efficient training programs such as HIIT remains a topic of ongoing discussion.

1.2 High-intensity interval training in the military context

High-intensity interval training (HIIT) has emerged as a widely used method for improving physical fitness within a relatively short training duration. Previous studies have shown that HIIT can induce physiological adaptations commonly associated with traditional endurance training, including improvements in VO_2max, cardiovascular function, and metabolic efficiency [11, 14].

In addition to aerobic adaptations, HIIT also stimulates anaerobic energy systems through repeated high-intensity efforts. This dual effect is particularly relevant in military settings, where physical performance often involves intermittent activity characterized by short bursts of high intensity interspersed with periods of lower intensity or recovery. Such demands closely resemble the structure of interval-based training, which may enhance the transfer of training adaptations to real operational conditions. Research focused on military populations suggests that interval-based approaches can improve both aerobic and anaerobic performance [12, 13].

From a practical perspective, HIIT represents a time-efficient training strategy, which is a critical factor in military environments where physical training must be integrated with tactical and technical preparation. Furthermore, HIIT can be implemented with minimal equipment and within limited space, making it suitable for both institutional training and field conditions.

Despite these advantages, the effects of HIIT on aerobic capacity in military populations remain inconsistent. While some studies report improvements in VO_2max, others indicate comparable or only marginal differences when compared with traditional training approaches [9, 14]. This suggests that the effectiveness of HIIT may depend on specific program design, population characteristics, and training context.

1.3 Research continuity and rationale

The training model applied in the present study has previously been investigated by the authors in relation to anaerobic performance, body composition, and subjective measures of physical readiness and stress management [2]. The results of that study indicated that a structured nine-week HIIT program was associated with greater improvements in anaerobic performance, particularly in male participants, although between-group differences did not reach statistical significance. No clear advantages were observed in body composition outcomes.

These findings suggest that HIIT may be particularly effective for developing anaerobic performance; however, its effect on aerobic capacity within the same population and training framework has not yet been clearly established. Given the importance of aerobic fitness for military performance, further investigation is warranted.

The present study therefore builds directly on previous research by focusing specifically on VO_2max as a primary outcome. By combining data from two consecutive training seasons with an identical intervention design, this study aims to provide a more robust evaluation of the effects of HIIT on aerobic capacity in military university students. Additionally, this research represents part of an ongoing longitudinal project planned over a five-year period, which aims to systematically monitor and evaluate physical fitness development in this population.

In particular, there is a lack of studies directly comparing structured HIIT interventions with conventional military physical training in a controlled university setting, especially with a focus on aerobic capacity. Together with previous findings focused on anaerobic performance, this approach allows for a more comprehensive understanding of the physiological adaptations associated with HIIT in military populations. The aim of this study was to evaluate the effects of a nine-week structured high-intensity interval training program on aerobic capacity (VO_2max) in military university students compared with conventional physical training.

2. Methods

2.1 Study design

This study was designed as a two-arm, parallel-group controlled intervention study conducted over a nine-week intervention period. Data were collected across two consecutive academic years (2024/2025 and 2025/2026), during which the same intervention protocol was applied.

The study represents part of an ongoing longitudinal project planned over a five-year period, aimed at monitoring and evaluating the development of physical fitness in military university students.

No formal a priori sample size calculation was performed. The sample size was determined by the number of eligible participants available within the existing organizational structure of the training program in each academic year, reflecting a pragmatic approach in a real-world military education setting. Participants were assigned to either the intervention group (HIIT) or the control group (CON) in accordance with the organizational structure of the training program.

2.2 Participants

Participants were recruited from a cohort of approximately 600 first-year cadets enrolled at the University of Defence in Brno, Czech Republic, across two academic years. Inclusion criteria were: (1) full-time enrolment as a first-year cadet; (2) successful completion of the mandatory physical fitness admission test (12-minute run and 1-minute sit-up test) at a level corresponding to at least an "average" performance; and (3) absence of medical contraindications to high-intensity exercise.

Exclusion criteria included any musculoskeletal injuries or medical conditions that would prevent full participation in the training program.

A total of 86 cadets (72 men and 14 women) met the inclusion criteria and provided written informed consent to participate in the study.

Group allocation. Participants were assigned to either the intervention group (HIIT) or the control group (CON) based on the existing organizational structure of the training program within the university. Both groups followed their respective training programs under comparable conditions in terms of training frequency and duration.

2.4 Interventions

Both groups participated in a nine-week training program consisting of two sessions per week, with at least 48 hours between sessions.

Intervention group (HIIT): The HIIT program was designed to reflect the physical performance requirements of military university students while incorporating established principles of high-intensity interval training [10, 1]. Each session included a warm-up, a main training phase, and a cool-down. The training content was aligned with the physical requirements assessed within the military curriculum.

The program was divided into two phases. The first phase (weeks 1–4) focused on running performance and upper-body strength development. It included interval running at intensities close to VO_2max (distances ranging from 50 to 500 m) and strength-oriented exercises. The second phase (weeks 5–9) incorporated elements of high-intensity functional training (HIFT), including multi-joint exercises such as squats, lunges, push-ups, TRX rows, and burpees. Work-to-rest ratios were manipulated using different interval formats (e.g., 20:10 s, 1:1, and similar variations) to achieve a high training stimulus [3].

Control group (CON): The control group followed the standard physical education curriculum of the university. Training frequency and duration were comparable to the HIIT group; however, the sessions were not systematically structured or periodized. Training typically included endurance running, calisthenics, and coordination exercises, without standardized control of training intensity.

2.5 Measurements

Anthropometric and performance measurements were conducted before and after the nine-week intervention under standardized conditions.

Anthropometric measurements. Body height was measured using standard procedures, and body mass was assessed using a bioelectrical impedance device (InBody 970, Biospace, South Korea). Body mass index (BMI) was calculated as body mass (kg) divided by height squared (m^2).

Aerobic capacity (VO_2max). Aerobic capacity was assessed using a maximal incremental spiroergometric test performed on a calibrated cycle ergometer (Monark 894 E, Sweden). Respiratory parameters were recorded using a portable metabolic system (Cortex MetaMax® 3B).

The test protocol began with a short warm-up at low intensity, followed by a gradual increase in workload until volitional exhaustion. After the test, participants completed a brief active recovery period at low intensity.

VO_2max was determined as the highest oxygen uptake value achieved during the maximal incremental test.

2.6 Statistical analysis

All statistical analyses were performed using standard statistical procedures. Descriptive statistics are presented as mean ± standard deviation (SD). The normality of data distribution was assessed using the Shapiro–Wilk test. Within-group changes in VO_2max (pre- vs. post-intervention) were evaluated using paired samples t-tests. Between-group differences in changes were assessed using independent samples t-tests based on change scores (Δ = post – pre). The level of statistical significance was set at $p < 0.05$.

Due to the small sample size, particularly in the female subgroup, analyses for women were considered exploratory and should be interpreted with caution. Data from the second season for female participants were not included in the main statistical analysis due to insufficient sample size.

3. Results

3.1. Participant characteristics

Baseline characteristics of male participants are presented in Table 1. Overall, participants in both groups were comparable in terms of body height, body mass, and BMI across both seasons. Minor differences were observed between groups, particularly in body mass and BMI values in the first season.

Table 1.

Baseline characteristics of male participants (mean ± SD)

Variable	HIIT Season 1 (n=28)	HIIT Season 2 (n=11)	CON Season 1 (n=21)	CON Season 2 (n=10)
Height (cm)	181.54 ± 6.89	181.00 ± 5.93	**183.14 ± 6.14**	182.80 ± 5.71
Body mass (kg)	80.84 ± 10.53	73.51 ± 8.57	**77.47 ± 9.33**	78.07 ± 9.49
BMI (kg/m²)	24.49 ± 2.51	22.44 ± 2.19	**23.13 ± 2.81**	23.33 ± 2.16

Values are presented as mean ± standard deviation (SD). HIIT: high-intensity interval training; CON: control group.

3.2 Changes in aerobic capacity (VO_2max)

The primary analysis was performed on pooled data from both seasons. In male participants, no statistically significant changes in VO_2max were observed following the intervention in either group. Within-group analyses showed no significant pre–post differences in the HIIT group (season 1: $p = 0.297$; season 2: $p = 0.548$) or in the control group (season 1: $p = 0.567$; season 2: $p = 0.876$).

In the HIIT group, VO_2max values showed a slight decrease across both seasons (season 1: $\Delta = -0.68 \pm 3.38$; season 2: $\Delta = -0.55 \pm 2.91$). In contrast, the control group demonstrated a small increase in the first season ($\Delta = +0.43 \pm 3.37$) and minimal change in the second season ($\Delta = +0.10 \pm 1.97$).

Between-group comparisons of change scores (Δ = post – pre) did not reveal statistically significant differences between the HIIT and control groups in either season (season 1: $p = 0.262$; season 2: $p = 0.556$) or when data were pooled ($p = 0.197$).

Overall, the magnitude of changes was small in both groups. Descriptive statistics for VO_2max are presented in Table 2.

Table 2.

Changes in VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$) in male participants (mean ± SD).

Group	Season	n	Pre (mean ± SD)	Post (mean ± SD)	Δ (post–pre) (mean ± SD)	p (within)
HIIT	1	28	47.21 ± 5.70	46.54 ± 6.19	−0.68 ± 3.38	0.297
CON	1	21	49.00 ± 7.28	49.43 ± 6.83	+0.43 ± 3.37	0.567
HIIT	2	11	50.55 ± 5.50	50.00 ± 4.38	−0.55 ± 2.91	0.548
CON	2	10	47.50 ± 6.33	47.60 ± 5.19	+0.10 ± 1.97	0.876

Notes: Values are presented as mean ± standard deviation (SD). Δ represents the change score (post – pre). HIIT: high-intensity interval training; CON: control group.

Female subgroup. In female participants, no statistically significant changes in VO_2max were observed in either the HIIT or control group ($p > 0.05$). In the first season, the HIIT group showed a slight decrease in VO_2max, whereas the control group demonstrated a small increase. However, the magnitude of these changes was minimal. Due to the small sample size, particularly in the second season, these findings should be interpreted with caution, and the results in female participants should be considered exploratory.

4. Discussions

The aim of the present study was to evaluate the effect of a nine-week structured high-intensity interval training (HIIT) program on aerobic capacity (VO_2max) in military university cadets. The main finding was that the intervention did not lead to a significant improvement in VO_2max compared to conventional physical training.

This finding may appear inconsistent with previous research, which has frequently reported positive effects of HIIT on aerobic capacity [10, 9, 11]. However, several factors should be considered when interpreting these results.

First, the duration of the intervention may have been insufficient to induce measurable changes in VO_2max. Although HIIT is generally considered an effective method for improving aerobic capacity, adaptations in VO_2max often require longer or more specifically targeted endurance-oriented training stimuli. The nine-week duration, combined with a relatively low training frequency (two sessions per week), may not have provided a sufficient cumulative stimulus to elicit significant cardiovascular adaptations.

Second, the structure of the HIIT program was not exclusively focused on aerobic development. While the intervention included running intervals near VO_2max intensity, a substantial part of the program incorporated strength-oriented and functional training elements (HIFT). These components are highly relevant for military performance but may dilute the specific stimulus required for maximizing improvements in aerobic capacity.

Third, the baseline fitness level of participants should be taken into account. The cadets included in the study had already met minimum physical performance requirements for admission, indicating a relatively homogeneous and moderately trained population. In such individuals, improvements in VO_2max are typically smaller and require either a higher training volume or more specifically targeted endurance-oriented interventions.

Interestingly, the results are consistent with findings from the authors' previous study, which demonstrated that the same HIIT intervention was effective in improving anaerobic performance but did not produce superior effects on body composition [2].

In addition, qualitative data from the same research project indicated that participants in the HIIT group reported higher perceived physical readiness and more favorable stress management outcomes compared to the control group. In addition to laboratory-based measurements, improvements were also observed in field-based performance tests, particularly in the 1 km run and pull-up performance, which were part of the standard physical assessment requirements. Although these outcomes were not the primary focus of the present analysis, they further support the practical effectiveness of the applied training program in improving performance-relevant abilities in military students. Taken together, these findings suggest that the applied training model may be more effective for developing anaerobic capacity and overall physical readiness rather than maximizing aerobic adaptations.

From a practical perspective, these results are important for the design of military training programs. While HIIT is often promoted as a time-efficient method for improving aerobic fitness, the present findings indicate that, in this specific setting, it may not provide a sufficient stimulus for increasing VO_2max when combined with other training modalities. However, this does not diminish its value, as HIIT may still contribute to improvements in other components of physical fitness that are critical for military performance.

4.1 Limitations

This study has several limitations that should be acknowledged. First, the sample size was relatively small, particularly in the female subgroup, which limits the generalizability of the findings and reduces the statistical power to detect small differences between groups.

Second, the duration and frequency of the intervention may have been insufficient to induce significant changes in aerobic capacity. A longer intervention period or higher training frequency could potentially lead to different outcomes.

Third, the allocation of participants to groups was influenced by the existing organizational structure of the training program, which reflects real-world conditions but may limit the level of experimental control.

An additional limitation is related to the standardized design of the training program. The intervention was developed to be applicable to a relatively large and heterogeneous group of participants, which limited the possibility for individualization of training load and intensity. As a result, the stimulus may not have been optimal for all individuals, potentially influencing the magnitude of observed adaptations.

Furthermore, participants' additional physical activity and lifestyle factors outside of the structured training sessions were not controlled, which may have influenced the observed results.

Finally, although VO_2max is a widely accepted indicator of aerobic capacity, it represents only one aspect of physical fitness. Other relevant performance variables were not included in this analysis.

Despite these limitations, the study provides valuable insight into the application of HIIT in a military education setting.

4.2 Practical implications

The findings of this study have important implications for the design of physical training programs in military education settings. The results indicate that a structured HIIT program, as applied in this study, may not be sufficient to significantly improve aerobic capacity (VO_2max) in moderately trained military students when performed twice per week over a nine-week period. When the primary goal is to enhance aerobic capacity, training programs should therefore include a higher volume of endurance-oriented training or more specifically targeted aerobic stimuli.

At the same time, the findings suggest that HIIT can be effectively integrated into military training programs to improve other components of physical fitness. Together with previous findings and observed improvements in field-based performance tests, the applied training model appears to be useful for supporting performance-relevant abilities such as short-term endurance, strength, and overall physical readiness.

From a practical perspective, HIIT remains a valuable training tool due to its time efficiency and flexibility. It can be effectively implemented in conditions with limited time, space, or equipment, which are typical for military environments. However, its use should be aligned with clearly defined training objectives. In practice, HIIT should not be considered a standalone solution for improving all components of physical fitness, particularly when the goal is to enhance aerobic capacity. Instead, it appears more appropriate to combine HIIT with other training methods, especially continuous or longer-duration endurance training. However, further research with larger samples and longer intervention periods is needed to confirm these findings.

5. Conclusions

In conclusion, the present study showed that a nine-week structured HIIT program performed twice per week did not lead to significant improvements in aerobic capacity (VO_2max) in military university cadets compared to conventional physical training.

However, the findings, together with previous results and observed improvements in anaerobic capacity and physical readiness, suggest that the applied training model may be effective for improving other components of physical fitness. Improvements in field-based performance tests further support the practical effectiveness of the intervention.

These results highlight the importance of aligning training methods with specific performance goals. While HIIT represents a time-efficient and practical training approach in military settings, its effectiveness for improving aerobic capacity may be limited when used as the primary training modality.

Further research is needed to better understand the long-term effects of HIIT on aerobic capacity in military populations.

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