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Impact of High-Intensity Interval Training on VO_2 Max among Male Collegiate Ice Hockey Players in China: A Pilot Study

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Abstract
This pilot study evaluated the effects of high-intensity interval training (HIIT) on maximal oxygen uptake (VO_2 max) among male collegiate ice hockey players in China. Using a cluster-randomized controlled trial (C-RCT) design, 18 participants aged 18 to 24 years were recruited and randomly assigned to either an experimental group (n = 9, receiving the HIIT intervention) or a control group (n = 9, receiving standard training). The intervention lasted two weeks, during which pre- and post-intervention assessments of VO_2 max were conducted. The results indicated no significant changes in VO_2 max within either group following the intervention, nor were there significant differences between groups. However, the HIIT group demonstrated a slight improvement in VO_2 max compared to the control group, although this did not reach statistical significance. These findings suggest that a short-term HIIT intervention has a limited impact on VO_2 max among collegiate ice hockey players. The study underscores the need for further research to explore the effects of varying intervention durations and training intensities on VO_2 max in ice hockey players, which could significantly impact training regimens and enhance aerobic endurance, potentially revolutionising how we train athletes.
Keywords: High-Intensity Interval Training (HIIT), Maximal Oxygen Uptake (Vo_2 Max), Fitness, Collegiate Hockey Players, Pilot Study

Introduction

In recent years, high-intensity interval training (HIIT) in physical conditioning has gained considerable attention. HIIT, which combines short, high-intensity intervals with low-intensity recovery periods, has been recognised as an effective training method (Evangelista et al., 2022; Gibala & Jones, 2013). Compared to traditional endurance training (ET), HIIT can achieve similar or superior cardiorespiratory fitness improvements in a shorter time, making it particularly appealing to time-constrained athlete populations (Milanović et al., 2015). Furthermore, HIIT has demonstrated benefits in improving anaerobic metabolism, muscle strength, and cardiovascular fitness (Weston et al., 2014). The potential benefits of HIIT for enhancing maximal oxygen uptake (VO_2 max) in specific sports and population characteristics are yet to be fully explored, offering a promising avenue for future research. This potential for enhancing VO_2 max could be a game-changer in sports science and exercise physiology.

Traditional endurance training, characterised by prolonged, low- to moderate-intensity exercise, is commonly employed to enhance aerobic endurance. Its effect on VO_2 max tends to be stable but demands more time and offers less flexibility than HIIT (Milanović et al., 2015; Obradović et al., 2016). Conversely, HIIT has effectively increased VO_2 max in a shorter duration by stimulating rapid adaptations in the cardiorespiratory system through short bursts of high-intensity exertion (Acosta et al., 2022). Consequently, HIIT is increasingly being adopted across various sports, including intermittent sports such as football, basketball, and ice hockey.

As a high-intensity intermittent sport, ice hockey imposes significant demands on aerobic and anaerobic endurance. Players must perform frequent short bursts of high-intensity sprinting, stopping, and turning, challenging cardiorespiratory endurance and muscle metabolism (Vigh-Larsen & Mohr, 2024). VO_2 max is essential for assessing athletes' aerobic capacity, influencing their performance in high-intensity matches and providing insight into long-term training effects (Ranković et al., 2010). However, regarding the specific impact of HIIT on VO_2 max in ice hockey players, most studies have focused on adult athletes or non-domestic groups, with a relative lack of research on collegiate athletes, especially Chinese college ice hockey players.

Thus, the present study aimed to investigate the effects of HIIT on VO_2 max in Chinese male collegiate ice hockey players. By comparing the effects of HIIT with conventional training, this study seeks to provide empirical support for training strategies among collegiate ice hockey players and lay the foundation for future large-scale intervention studies. We hypothesised that the HIIT intervention would significantly enhance VO_2 max in the experimental group, offering a theoretical basis for optimising aerobic training protocols for ice hockey players.

Materials and Methods

Study Design

This study employed a C-RCT design in which participants were randomly assigned to either an experimental or control group. The experimental group received a HIIT intervention, while the control group continued with regular hockey training. The intervention lasted two weeks, with three training sessions per week, each lasting 50 minutes. All sessions were conducted in the same indoor ice rink and supervised by experienced coaches.

Participants

Eighteen Chinese male collegiate ice hockey players (aged 18-24) from the Henan University of Technology ice hockey team participated in the study. The medical Ethics Committee approved the study, and all participants provided written informed consent. Table 1 presents the inclusion and exclusion criteria for the experimental sample in detail.

Table 1
Inclusion and Exclusion Criteria for Participants

Criteria	Details
Inclusion Criteria	a) Healthy male ice hockey players aged 18-24 years. b) At least 1 to 3 years of ice hockey training experience. c) No previous experience with HIIT. d) No concurrent physical training interventions during the study. e) No medications affecting athletic performance. f) No history of major sports injuries.
Exclusion Criteria	a) History of knee, shoulder, or other significant injuries. b) Participation in HIIT training within the past year. c) History of alcohol or illicit drug use. d) Inability to consistently participate in the training program.

Participants who met all criteria were enrolled in the study. Before starting the intervention, participants received detailed instructions on the HIIT protocol, including proper warm-up and cool-down techniques, to minimise injury risk and enhance training effectiveness.

HIIT Intervention Design

The structure and intensity monitoring of the HIIT sessions implemented in the study are outlined below. Each training session was designed with distinct phases to ensure comprehensive preparation, effective intensity management, and appropriate recovery. Table 2 provides details of the warm-up, main HIIT components, cool-down, and intensity monitoring measures.

Table 2
Training Structure and Intensity Monitoring for HIIT Sessions

Training Structure	Details
Warm-Up (10 min)	Dynamic stretching and low intensity gliding to raise heart rate progressively.
HIIT (30 min)	Four sets of high-intensity work phases, including: **Work Phase:** 15-30 seconds of sprint gliding, specialised drills (e.g., long-pass tracking drill, chase-the-rabbit drill). Target intensity: 85-95% of maximum heart rate. **Recovery Phase:** 30 seconds to 2 minutes of low intensity gliding or standing rest after each work phase.
Cool-Down (10 min)	Slow gliding and static stretching to facilitate relaxation.
Training Intensity Monitoring	**Details**
Heart Rate Monitoring	Participants wore heart rate monitors to ensure their heart rate remained in the target zone (85-95% of maximum heart rate). Coaches calibrated devices before each session.
Coach Feedback	Coaches supervised all sessions to ensure proper form and adjusted pace and intensity based on real-time heart rate feedback.
Fatigue Monitoring	Participants self-assessed intensity and fatigue using the Rating of Perceived Exertion (RPE) scale (6-20 points).

Control Group Training

The control group continued with regular hockey training, consisting of 50-minute sessions focused on basic skating, passing, sprinting drills, and tactical exercises. The training intensity was maintained to match but not duplicate that of the experimental group.

Measurements and Assessments

i. *VO_2 Max Measurement*

VO_2 max was assessed using the Cooper 12-minute running test (Cooper, 1968). All participants were tested at the same venue and instructed to run as far as possible in 12 minutes. Running distance was recorded, and VO_2 max was calculated using a standard formula.

ii. *Fatigue Assessment*

RPE scores collected after each training session monitored fatigue and provided insights into adjusting training intensity.

Intervention Implementation and Control

i. *Consistency Control*

All training sessions were conducted at the same ice rink, supervised by two HIIT-qualified coaches. Before training, coaches instructed participants on correct sprint skating posture and exercise specifications to ensure consistency.

ii. *Intensity Control*

The coach adjusted intensity and recovery time in real-time based on heart rate monitoring and RPE scores to ensure participants trained within the intended intensity range.

iii. *Control Group Supervision*

The same coaching team supervised the control group's routine training to maintain consistency and standardisation.

Statistical Analyses

The statistical analyses focused on assessing the effects of HIIT on VO_2 max in Chinese male collegiate ice hockey players. Descriptive and inferential statistics were employed to evaluate the intervention effects fully. All data were analysed using SPSS software (version 28; IBM Corporation, Chicago, Illinois, USA) with the significance level set at $p < 0.05$ (two-sided). Before analysis, rigorous data cleaning was performed, addressing missing values and outliers to ensure data quality and accuracy.

Results

Independent t-tests were conducted to assess homogeneity between the groups concerning baseline characteristics such as age, height, weight, body mass index (BMI), and experience to assess homogeneity between the groups, as these variables were normally distributed. The results (Table 3) indicated no significant differences between the HIIT and control groups in terms of age ($t = 0.091$, $p = 0.902$), height ($t = -0.068$, $p = 0.913$), weight ($t = 0.150$, $p = 0.873$), BMI ($t = 0.281$, $p = 0.776$), and experience ($t = -0.141$, $p = 0.890$). These findings suggest that both groups were comparable at baseline, with no significant differences in the key demographic and training-related variables.

Table 3
Pre-test Characteristics of Participants in the Two Study Groups

	Groups	Mean	SD	t value	p-value
Age (year)	HIIT	20.50	1.56	0.091	0.902
	CG	20.45	1.53		
Height (cm)	HIIT	176.25	4.20	-0.068	0.913
	CG	176.05	3.46		
Weight (kg)	HIIT	68.05	5.49	0.150	0.873
	CG	67.90	5.38		
BMI (kg/m²)	HIIT	21.35	2.05	0.281	0.776
	CG	21.29	1.67		
Experience (month)	HIIT	23.70	3.47	-0.141	0.890
	CG	23.75	3.52		

The Generalised Estimation Equation (GEE) model was used to assess the intervention's effect on VO_2 max within each group and analyse changes in the mean VO_2 max scores at two time points (pre-test and post-test). Table 4 presents descriptive statistics for both groups at each time point, including means and standard errors.

Table 4
Descriptive Statistics of VO_2 max for Both Groups Across the Time

Groups	Time	Mean	SE
HIIT	**Pre-test**	46.35	1.16
	Post-test	47.05	1.17
CG	**Pre-test**	46.70	1.10
	Post-test	46.50	1.08

As shown in Table 5, the GEE analysis yielded results that were not statistically significant. The findings indicated no significant relationship between time and VO_2 max ($\chi 2$ = 2.054, p = 0.206), suggesting no substantial changes in VO_2 max levels over time. Additionally, the effect of the group on VO_2 max was not statistically significant ($\chi 2$ = 3.28, p = 0.290), indicating no significant difference in VO_2 max between the experimental and control groups. Furthermore, the analysis revealed no significant interaction effect between time and group ($\chi 2$ = 2.907, p = 0.062), suggesting that changes in VO_2 max over time did not differ significantly between the groups.

Table 5
Results of Generalised Estimating Equations for VO_2 max

Source	Wald Chi-Square	df	P value
Groups	2.054	1	0.206
Time	3.28	2	0.290
Time * Group	2.907	2	0.062

**: Significant at 0.05 level.*

A comparison of the mean values of maximal oxygen uptake between the HIIT and control group at different time points (pre-test and post-test) is presented in Table 6. The table includes mean differences, standard errors (SE), p-values, 95% confidence intervals (CI) for differences, and effect sizes (d). These results showed no statistically significant difference between the two groups at pre-test (p = 1.00) or post-test (p = 0.07). The post-intervention effect size indicated a small practical significance (d = 0.23).

Table 6
Pairwise Mean Comparison of VO_2 max Between HIIT and CG Across the Time. (Between Groups)

Group	**Time**	**Mean Difference**	**SE**	**P value**	**95%CI for Difference**		**Effect Size d**
					LB	**UB**	
Pre-test	HIIT Vs. Control	0.33	1.60	1.00	-2.73	3.58	0.06
Post-test	HIIT Vs. Control	1.05	1.62	0.08	-1.19	6.08	0.23

** The mean difference is significant at the .05 level. Adjustment for multiple comparisons: Bonferroni.*

Table 7 compares each group's mean VO_2 max values at pre-test and post-test. The results show no statistically significant improvement in VO_2 max in the HIIT group from the pre-test to the post-test (p = 0.061). The time effect size for the HIIT group indicated a small effect (d = 0.25). Similarly, no significant improvement in VO_2 max was observed in the control group (p = 0.083), and the effect size suggested a minimal impact (d = 0.03) compared to the HIIT group.

Table 7
Pairwise Mean Comparison for VO_2 max Across the Time in Both Groups.
(Within Group)

Group	**Test**	**Mean Difference**	**SE**	**P value**	**95%CI for Difference**		**Effect Size d**
					LB	**UB**	
HIIT	Pre-test vs. Post-test	-3.34	0.24	0.061	-4.02	-2.70	0.25
Control	Pre-test vs. Post-test	0.49	0.65	0.083	-1.41	1.44	0.03

** The mean difference is significant at the .05 level. Adjustment for multiple comparisons: Bonferroni.*

Discussion
This study aimed to investigate the effects of short-term HIIT on VO_2 max in Chinese male collegiate ice hockey players. The study results indicated a trend of improvement in VO_2 max within the HIIT group following the intervention, with a mean increase of 1.05. Within-group comparisons also showed slight improvement, with a mean increase of 0.22. However, the between-group and within-group differences did not reach statistical significance (p > 0.05).

Despite this, although small, the between-group effect size (d = 0.23) and the within-group effect size for the HIIT group (d = 0.25) suggested an initial short-term impact of HIIT training, providing valuable insights for future studies involving more extended intervention periods. Furthermore, the range of 95% confidence intervals (-1.19 to 6.08; -4.02 to -2.70) indicates that the effects of training may become more pronounced with increased sample size and extended intervention duration.

Comparative Analysis with Other Studies

The results of this study are consistent with findings from Weston et al. (2014) and Burgomaster et al. (2008), whose studies showed that shorter HIIT interventions had limited improvements in VO_2 max. In contrast, longer interventions tended to yield significant results. Compared to the substantial enhancement observed in the 6-week HIIT study by Iaia et al. (2009), the 2-week intervention in the present study may have been insufficient to elicit adequate cardiorespiratory adaptation. This suggests that improving VO_2 max through HIIT requires a more extended intervention to remodel the aerobic system fully.

Furthermore, Buchheit and Laursen (2013) HIIT requires high-intensity stimulation, adequate training frequency, and recovery time to enhance cardiorespiratory fitness. Although HIIT training was performed three times weekly in this study, the total intervention duration was more extended, which may have contributed to the lack of significant effects. Future studies could increase the number of training weeks and the training frequency to determine if a more extended intervention would lead to substantial changes.

Differences in the Effect of HIIT across Exercise Programs

Studies have shown that the effect of HIIT on VO_2 max enhancement may vary depending on the sport's characteristics. In intermittent sports such as ice hockey, athletes must perform frequent short sprints, skates, stops, and turns (Talsnes et al., 2021), which places higher demands on the anaerobic system and fast-twitch muscle fibres. HIIT, however, is highly compatible with these exercise demands through short bursts of high-intensity stimulation. Therefore, although the present study failed to significantly enhance VO_2 max, the HIIT training paradigm still holds potential applications in ice hockey.

HIIT is more compatible with ice hockey games' high-intensity, short-interval characteristics than traditional, long-duration, low-to-moderate-intensity endurance training. For example, Talsnes et al. (2021), suggested that conventional training tends to build base endurance. In contrast, HIIT's interval training simulates the high-intensity work demands of the game, which may positively impact athletes' game performance. Future research could further validate the specific effects of HIIT in ice hockey by assessing actual game metrics (e.g., sprinting speed, sharp stopping, and turning ability).

Potential and Trend Analysis of VO_2 max Improvement

Although the VO_2 max improvement in this study did not reach statistical significance, the observed trend of improvement in the HIIT group suggests that this training modality still has the potential to improve cardiorespiratory fitness. HIIT can activate fast-twitch muscle fibres and increase the efficiency of oxygen utilisation during high-intensity interval exercise (Iaia et al., 2009). This gradual adaptation may result in more significant VO_2 max gains with a more extended intervention period. Especially in an intermittent sport like ice hockey, the application of HIIT may better align with the game's physical demands. The efficiency of HIIT also makes it ideal for time-constrained athletes. When training time is limited, HIIT provides an effective means of cardiorespiratory training. Although this study did not show significant enhancement, HIIT can enhance cardiorespiratory fitness through high-intensity stimulation as a supplement to traditional training.

Recommendations for Future Research

The results of this study provide an initial reference for training strategies for ice hockey players while also indicating the need for further optimisation of training parameters. The following directions for improvement could be considered for future research:

a) Extend the Duration of the Intervention: An intervention cycle of 8-12 weeks should be used to adequately capture the long-term effects of HIIT on VO_2 max, an intervention cycle of 8-12 weeks should be used.
b) Adjust Training Frequency and Intensity: Increase the number of training sessions per week or increase the training load during the high-intensity phase.
c) Incorporate More Testing Metrics: In addition to VO_2 max, measurements of actual performance metrics, such as sprint speed and recovery time, can be used to validate the practical application of HIIT.
d) Expand the Sample: Future studies should include athletes of different genders, ages, and competitive levels to evaluate the effects of HIIT on a broader population.

Although the present study failed to improve VO_2 max in the short term significantly, the improvement trend in the HIIT group suggests that this training mode can potentially improve cardiorespiratory capacity in hockey players. Compared to traditional endurance training, HIIT's high intensity and short duration are highly compatible with the demands of ice hockey. Future studies should extend the intervention duration and optimise the training protocol to assess the effects of HIIT more fully on cardiorespiratory adaptations and game performance in ice hockey players.

Limitations

This study has several limitations, centred around sample size, intervention duration, and the selection of study participants. The following provides further explanation of these limitations and explores future directions for improvement:

i. Sample Size Limitations

The small sample size of eighteen participants in this study limits the statistical power and may have contributed to differences between groups failing to reach significance. Additionally, the small sample size also limits the generalisability of the findings. Although participant recruitment conditions and scheduling constraints limited the sample size, there is some comparability between this sample size and other similar studies. For example, some ice hockey or HIIT-related studies have also used small sample sizes (e.g., 15-30 athletes) to ensure rigour in controlling experimental variables. However, future studies should expand the sample size to improve statistical power and reduce the impact of data variability.

ii. Duration of the Intervention

The duration of the HIIT intervention in this study was two weeks, three times per week, for a total of six training sessions. Time constraints and the academic commitments of participants primarily influenced this schedule. However, evidence suggests that HIIT interventions lasting 8-12 weeks typically yield more significant improvements in aerobic metrics such as VO_2 max (Milanović et al., 2015; Ní Chéilleachair et al., 2017; Wen et al., 2019). A two-week intervention may not be sufficient to observe substantial changes in VO_2 max. However, short-term interventions can still be used to provide initial insights into the effects of HIIT on cardiorespiratory fitness in athletes. Future studies should maximise intervention duration to capture longer-term changes in aerobic adaptation.

iii. Study Population Limitations
The population of this study was Chinese male collegiate ice hockey players. The homogeneity of this group helped control study variables but also limited the generalisability of the results. There may be differences in the response to HIIT among athletes of different genders, ages, or competitive levels. For instance, female or older athletes may differ in their capacity to recover and adapt compared to younger male athletes. Therefore, future studies should expand the study population to include female athletes, individuals of different ages, and other competitive levels to assess the effects of HIIT more comprehensively on various populations.

Conclusion
The present study demonstrated that a two-week HIIT intervention did not result in a statistically significant increase in VO_2 max among Chinese male collegiate ice hockey players. However, an initial positive trend was observed. This suggests that more than short-term HIIT interventions may be required to trigger significant aerobic adaptations. However, HIIT may still hold promise as a supplementary training tool for situations with limited time availability. For practical training purposes, it is recommended that coaches incorporate HIIT alongside regular training sessions while optimising training loads with tools such as heart rate monitoring and Rating of Perceived Exertion (RPE) scoring to avoid overtraining. Extending the duration of the intervention to 8-12 weeks, increasing the training frequency, or introducing higher-intensity phases may result in more substantial improvements in VO_2 max and enhanced game performance. Future studies should also explore the effects of various training parameters and include real-world performance metrics, such as sprint speed and recovery time, to fully evaluate HIIT's impact on athletic performance.

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Conflict of Interest
The authors declare no conflicts of interest relevant to this work.

Author Contributions
All authors contributed equally to the manuscript's conception, design, and preparation.

Data Availability Statement
The datasets generated and analysed during the current study are available from the corresponding author upon reasonable request.

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