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Effects of High-Intensity Interval Training on Aerobic Capacity and Cardiovascular Function in Male University Hockey Athletes: A Randomized Controlled Trial

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Abstract

Background: *High-Intensity Interval Training (HIIT) has gained widespread recognition as an effective conditioning strategy in team sports, yet its application among university-level hockey athletes in Pakistan remains largely unexplored.* ***Objective:*** *This study investigated the effects of an 8-week HIIT program on aerobic capacity and cardiovascular function in male university hockey players.* ***Methods:*** *Using a randomized controlled design, 30 male hockey players (M age = 21.73 ± 2.15 years) were randomly allocated to an experimental group (n = 15) that underwent a progressive HIIT protocol three sessions per week at 80–95% of maximum heart rate, or a control group (n = 15) that continued routine training. Primary outcomes VO2max and Yo-Yo Intermittent Recovery Test level were assessed alongside cardiovascular indicators (heart rate during exercise, heart rate recovery at 5 minutes post-exercise and resting blood pressure). Within-group and between-group comparisons were conducted using paired-samples and independent-samples t-tests (α = .05).* ***Results:*** *The experimental group demonstrated significant post-intervention gains in VO max (52.09 ± 2.43 vs. 49.10 ± 1.63 $mL \cdot kg^{-1} \cdot min^{-1}$; t[28] = 3.949, p < .001) and Yo-Yo performance (18.73 ± 1.91 vs. 16.13 ± 1.51 levels; t[28] = 4.144, p < .001) relative to controls. Heart rate recovery at 5 minutes improved significantly within the experimental group (p < .001), reflecting enhanced autonomic efficiency. Blood pressure showed no statistically significant between-group difference (p = 1.000).* ***Conclusion:*** *An 8-week HIIT program substantially enhances aerobic capacity and endurance performance in university hockey athletes. Integration of progressive HIIT protocols into structured conditioning programs is recommended for this population.*

Keywords: *high-intensity interval training, VO_2 max, aerobic capacity, cardiovascular function, field hockey, university athletes*

Introduction

Contemporary field hockey demands repeated high-intensity sprints, rapid directional changes, and sustained aerobic output over 60 or more minutes of match play. Players routinely operate at 85–90% of their maximum heart rate, relying on both aerobic and anaerobic energy systems in alternating fashion (Burr et al., 2015; Lythe & Kilding, 2021). Meeting these physiological requirements necessitates training interventions that replicate match-specific intensity patterns and elicit meaningful adaptations in endurance capacity and cardiovascular efficiency.

High-Intensity Interval Training (HIIT) characterized by brief, near-maximal work bouts interspersed with active or passive recovery has emerged as one of the most extensively studied conditioning strategies in sports science. Because HIIT mirrors the intermittent structure of team sport competition, it is considered particularly appropriate for athletes who must perform repeated sprints with limited recovery time (MacInnis & Gibala, 2017). Meta-analytic evidence confirms that HIIT produces significant improvements in maximal oxygen uptake (VO_2max) across athletic populations, typically in the range of 5–15% following 4–8 weeks of training (Viana et al., 2022). Moreover, recent systematic reviews report that HIIT enhances sport-specific endurance performance, heart rate recovery, and key cardiovascular markers (Qi et al., 2026; Roczniok et al., 2025).

Despite robust international evidence, the application of HIIT within university-level hockey populations in Pakistan has received limited empirical attention. Most available domestic research is descriptive, focusing on anthropometric or general fitness profiles rather than controlled training interventions (Bashir et al., 2023; Javed et al., 2016). Consequently, coaches and strength and conditioning practitioners at this level lack locally validated protocols. The present study addresses this gap by examining the effects of a structured, progressive 8-week HIIT program on aerobic capacity (VO2 max), endurance performance (Yo-Yo Intermittent Recovery Test), and cardiovascular indicators in male university hockey players under a randomized controlled design.

Methods

Participants

Thirty male hockey players (M age = 21.73 ± 2.15 years; M height = 5'8.5" ± 2.0 in; M body mass = 73.10 ± 6.70 kg) were recruited from two higher education institutions in Lahore, Pakistan the University of the Punjab (n = 15) and the University of Central Punjab (n = 15). All participants were actively competing in university-level hockey and had at least one year of structured training experience. Inclusion required medical clearance, age between 18 and 25 years, and consistent training attendance. Individuals with recent musculoskeletal injuries, cardiovascular disorders, or respiratory conditions were excluded. Prior to data collection, written informed consent was obtained from each participant. The study was conducted in accordance with the Declaration of Helsinki, and approval was granted by the Department of Sports Sciences and Physical Education, University of the Punjab.

Research Design

A randomized controlled experimental design with pre-test and post-test measurements was employed. Following baseline assessment, participants were randomly assigned to an Experimental Group (n = 15) or a Control Group (n = 15). Randomization was performed using a coin-toss procedure to ensure equal representation. The intervention lasted 8 weeks, and all testing and training sessions took place at the sports grounds of the University of the Punjab under standardized environmental conditions.

HIIT Intervention Protocol

The experimental group completed a progressive HIIT program three sessions per week for 8 weeks. Each session followed a standardized structure: 10-minute warm-up (light jogging, dynamic stretching, mobility work), 15–25 minutes of high-intensity intervals (sprint runs, shuttle runs, sport-specific agility drills), 20–25 minutes of supplementary conditioning (bodyweight exercises: lunges, squats, jump squats; 4 sets × 10–12 repetitions), and a 5-minute cool-down.

The training was periodized across four phases. During weeks 1–2 (Adaptation Phase), participants performed 10-second work bouts at 80–85% of maximum heart rate (MHR) with 30-second recovery intervals (10 rounds; 30–35 min). In weeks 3–4 (Progressive Overload), the work-to-rest ratio was reduced to 10:20 seconds at 90% MHR (12 rounds; 35–40 min). Weeks 5-6 (High-Intensity Phase) extended work bouts to 15 seconds at 90–95% MHR (12–14 rounds). Finally, weeks 7–8 (Peak Phase) maintained 15-second work bouts at 90–95% MHR with shortened 20-second recovery intervals (10 rounds; 35–40 min). All sessions were supervised by qualified coaches affiliated with the Pakistan Hockey Federation. The control group continued their standard training regimen continuous moderate-intensity running at 60–70% MHR for 30–40 minutes per session with no additional HIIT prescription.

Outcome Measures

Aerobic capacity was assessed via predicted VO2 max using a standardized field protocol widely applied in team sport settings (Buchheit & Laursen, 2013). Endurance performance was evaluated using the Yo-Yo Intermittent Recovery Test Level 1 (Bangsbo et al., 2008), which requires athletes to complete 20-meter shuttle runs at progressively increasing speeds interspersed with 10-second active recovery jogs; the final completed level was recorded. Cardiovascular function was assessed through (a) heart rate during maximal exercise recorded by a heart rate monitor, (b) heart rate recovery at 5 minutes post-exercise cessation, and (c) resting blood pressure measured by a calibrated digital sphygmomanometer following American Heart Association (2017) guidelines. All instruments were calibrated prior to each testing session, and assessors were blinded to group allocation during data entry.

Statistical Analysis

All analyses were performed using IBM SPSS Statistics (version 26.0). Descriptive statistics (mean ± SD) were calculated for all outcome variables. Paired-samples t-tests examined within-group pre-to-post changes, while independent-samples t-tests evaluated between-group differences at post-test. Statistical significance was set at $\alpha = .05$ and 95% confidence intervals (CIs) were reported for all mean differences. Pearson correlations between pre- and post-test scores were also computed to assess measurement reliability.

Results

Demographic Characteristics

Participants were young adult athletes with a mean age of 21.73 years (SD = 2.15), consistent with a university-level competitive sample. Height and body mass showed moderate variability, reflecting diverse physical builds suited for competitive hockey (Table 1).

Table 1

Demographic Characteristics of Participants (N = 30)

Variable	Mean	SD	Range
Age (years)	21.73	2.15	18–25
Height (ft)	5'8.5"	2.0 in	5'5"–6'0"
Weight (kg)	73.10	6.70	66–87

Note. Height is reported in feet and inches; body mass in kilograms.

Within-Group Pre-to-Post Changes

Paired-samples t-test results for the combined sample are presented in Table 2. Significant pre-to-post improvements were observed in Yo-Yo level (M difference = 1.80; t29 = 6.924, p < .001), VO2 max (M difference = 1.97 $\mathrm{mL{\cdot}kg^{-1}{\cdot}min^{-1}}$; t29 = 6.266, p < .001), and HR during exercise (M difference = 2.53 Bpm; t29 = 20.362, p < .001). Of particular physiological interest, HR recovery at 5 minutes post-exercise decreased significantly (M difference = −10.40 Bpm; t29 = −70.007, p < .001), indicating markedly improved parasympathetic reactivation. Blood pressure showed a small reduction that did not reach statistical significance t29 = −5.385, p = .077).

Table 2

Paired-Samples Statistics, Correlations, and t-Test Results (N = 30)

Measure	Pre M (SD)	Post M (SD)	n	r	t	df	p	95% CI
Yo-Yo (level)	15.63 (1.73)	17.43 (2.14)	30	.750	6.924	29	< .001	1.27, 2.33
VO2 max ($\mathrm{mL{\cdot}kg^{-1}{\cdot}min^{-1}}$)	48.62 (1.69)	50.59 (2.54)	30	.737	6.266	29	< .001	1.33, 2.62
HR During Exercise (bpm)	186.40 (3.81)	188.93 (3.41)	30	.988	20.362	29	< .001	2.28, 2.79
HR Recovery at 5 min (bpm)	137.83 (5.69)	127.43 (5.30)	30	.991	−70.007	29	< .001	10.70, −10.10
Blood Pressure (category)	3.70 (0.47)	3.20 (0.41)	30	.327	−5.385	29	.077	−0.69, −0.31

Note. M = mean; SD = standard deviation; r = Pearson correlation between pre- and post-test scores; CI = confidence interval for the mean difference. p values < .05 denote statistical significance.

Between-Group Comparisons at Post-Test

Both groups were statistically equivalent on all dependent variables at pre-test (all p > .50), confirming successful randomization. Post-intervention between-group comparisons are summarized in Table 3. The experimental group scored significantly higher on the Yo-Yo test (18.73 ± 1.91 vs. 16.13 ± 1.51 levels; t28 = 4.144, p < .001; 95% CI 1.32, 3.89 and VO2 max (52.09 ± 2.43 vs. 49.10 ± 1.63 $\mathrm{mL{\cdot}kg^{-1}{\cdot}min^{-1}}$; t28 = 3.949, p < .001; 95% CI 1.44, 4.54 relative to controls. No significant between-group differences emerged for HR during exercise (p = .530), HR recovery at 5 minutes (p = .763), or blood pressure (p = 1.000).

Table 3

Independent Samples t-Test Results: Experimental vs. Control Group Pre- and Post-Test Outcomes

Variable	Group	Pre M (SD)	Post M (SD)	t	df	p	95% CI (Post)
Yo-Yo (level)	Experimental	15.60 (1.72)	18.73 (1.91)	4.144	28	< .001	1.32, 3.89
	Control	15.67 (1.80)	16.13 (1.51)	—	—	—	—
VO2 max ($\mathrm{mL{\cdot}kg^{-1}{\cdot}min^{-1}}$)	Experimental	48.57 (1.66)	52.09 (2.43)	3.949	28	< .001	1.44, 4.54
	Control	48.67 (1.78)	49.10 (1.63)	—	—	—	—
HR Recovery 5 min (bpm)	Experimental	138.13 (5.00)	127.73 (4.57)	0.305	28	.763	−3.43, 4.63

Variable	Group	Pre M (SD)	Post M (SD)	t	df	p	95% CI (Post)
	Control	137.53 (6.47)	127.13 (6.09)	—	—	—	—
Blood Pressure	Experimental	3.73 (0.46)	3.20 (0.41)	0.000	28	1.000	−0.31, 0.31
	Control	3.67 (0.49)	3.20 (0.41)	—	—	—	—

Note. M = mean; SD = standard deviation; t and p refer to independent-samples t-test between Experimental and Control groups at post-test; CI = 95% confidence interval for the post-test mean difference. Pre-test values are presented for reference; no significant pre-test differences were observed (all p > .50).

Discussion

The principal finding of this investigation is that an 8-week progressive HIIT program produced statistically significant and practically meaningful improvements in both aerobic capacity and sport-specific endurance performance in male university hockey players, while a control group continuing routine training did not exhibit comparable gains. These results extend the growing body of evidence supporting HIIT as a time-efficient conditioning strategy for intermittent team sports (MacInnis & Gibala, 2017; Viana et al., 2022).

The observed increase in VO2 max (approximately 3.52 $mL\cdot kg^{-1}\cdot min^{-1}$, or roughly 7.3% above controls at post-test) is consistent with the range typically reported following 4–8 weeks of HIIT. The underlying mechanisms likely include increased stroke volume and cardiac output resulting from repeated myocardial demands placed by high-intensity bouts, alongside peripheral adaptations such as enhanced mitochondrial density and capillarization (Helgerud et al., 2021; Granata et al., 2021). Because higher VO2 max is associated with improved repeated sprint ability and faster lactate clearance, these adaptations are directly relevant to match performance in hockey (Roczniok et al., 2025).

The significant gain in Yo-Yo Intermittent Recovery Test performance approximately 2.60 levels above controls corroborates findings from sport-specific HIIT studies. Saha et al. (2025) reported comparable improvements in aerobic endurance and sprint performance among field hockey players after 6 weeks of HIIT, while Singh et al. (2023) documented enhanced anaerobic endurance following interval-based training in adolescent hockey players. The Yo-Yo test closely replicates the stop-and-go demands of match play, making it a particularly sensitive indicator of hockey-relevant fitness. Improvements on this test therefore imply that HIIT-trained athletes are better equipped to sustain high-intensity efforts across all phases of a match.

A noteworthy within-group finding was the significant reduction in HR at 5 minutes post-exercise in the experimental group (M difference = −10.40 bpm; $p < .001$), reflecting accelerated parasympathetic reactivation. Faster heart rate recovery following exercise is a recognized marker of enhanced cardiovascular fitness and improved autonomic nervous system regulation (Daanen et al., 2021). This adaptation is especially valuable in hockey, where players cycle rapidly between periods of intense activity and brief recovery, and suggests that HIIT-conditioned athletes can restore homeostasis more efficiently between high-intensity bouts.

In contrast, no significant between-group differences were observed for blood pressure. This finding aligns with previous research demonstrating that exercise-induced reductions in blood pressure are more pronounced in sedentary or hypertensive individuals than in already-trained athletes (Costa et al., 2022). The athletes in the present study likely had relatively healthy baseline cardiovascular profiles, leaving limited physiological headroom for detectable blood pressure change within an 8-week window. Longer interventions or populations with elevated baseline values may yield different outcomes.

Similarly, no significant between-group difference emerged for HR during maximal exercise. Peak HR is widely acknowledged as a relatively stable physiological ceiling governed primarily by genetics and age rather than training status (McArdle et al., 2015). Consequently, meaningful training-induced changes in this parameter are uncommon, and post-test group equivalence in peak HR should not be interpreted as an absence of cardiovascular adaptation.

The present findings must be interpreted within several limitations. The sample was confined to male university athletes from two institutions in Lahore, restricting generalizability to other demographic groups and competitive contexts. The 8-week intervention may have been insufficient to induce statistically discernible changes in blood pressure. Additionally, dietary intake, sleep quality, and habitual activity outside prescribed sessions were not formally monitored, though both groups trained under identical environmental conditions and similar schedules. Future work should incorporate longer interventions, female athlete cohorts, and multivariate control of lifestyle variables. Objective monitoring via GPS and wearable heart rate sensors would also strengthen internal validity and allow more nuanced load management.

Conclusion

An 8-week progressive HIIT program significantly improved aerobic capacity and endurance performance in male university hockey athletes compared to a control group continuing routine training. Improved heart rate recovery further indicated enhanced autonomic and cardiovascular efficiency. These physiological adaptations are directly relevant to the repeated high-intensity demands of competitive hockey. Blood pressure and peak exercise heart rate were unaffected, likely reflecting the already-trained nature of participants and the constraints of a short-term intervention. Collectively, these findings provide empirical support for incorporating periodized HIIT protocols into university-level hockey conditioning programs.

Practical Implications and Recommendations

Based on the study's findings, the following evidence-informed recommendations are offered for coaches, sports scientists, and conditioning professionals working with university hockey athletes:

1. Periodized HIIT integration: HIIT sessions should be scheduled 2–3 times per week within a structured conditioning plan. Initiating with conservative work-to-rest ratios (1:3) and progressively reducing recovery periods toward a 1:1 ratio over 8 weeks optimizes adaptation while minimizing injury risk.
2. Intensity prescription: Exercise intensity of 85–95% MHR should be monitored using wearable heart rate devices to ensure training stimuli are sufficient to elicit cardiovascular and metabolic adaptations.
3. Sport-specific drills: Shuttle runs, small-sided games, and sprint-with-ball-control exercises should constitute the core of HIIT work bouts to maximize transfer to match-specific movement patterns.

4. Recovery management: Adequate sleep, hydration, and nutritional strategies should be emphasized alongside the training program to maximize adaptation and reduce overtraining risk.
5. Institutional policy: Universities should formally incorporate HIIT-based conditioning modules within their sports science curricula and provide coaches with ongoing professional development in evidence-based training methods.

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