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Impact of High-Intensity Interval Training (HIIT) on Cardiovascular Endurance in Collegiate Athletes

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Abstract
Background: High-intensity interval training (HIIT) is widely promoted as a time-efficient method to enhance cardiorespiratory fitness, yet collegiate athletes operate within congested in-season calendars where conditioning time and recovery capacity are limited. Evidence specific to collegiate populations and practical HIIT prescription remains comparatively sparse.
Objective: To determine the effects of an 8-week HIIT mesocycle on cardiovascular endurance in collegiate athletes, using VO_2max as the primary outcome and Yo-Yo Intermittent Recovery Test Level-1 (Yo-Yo IR1) as a secondary sport-specific endurance marker.
Methods: In a randomized controlled pre-post design, 48 university athletes (18-24 years) were stratified by sport and sex and allocated to HIIT plus usual training or usual training alone. The HIIT group completed three supervised sessions weekly for 8 weeks using a long-interval 4×4-min protocol at 90-95% HR_max with 3-min active recoveries. VO_2max was assessed via graded treadmill testing with breath-by-breath gas analysis, and intermittent endurance via Yo-Yo IR1. Training intensity and internal load were monitored by heart rate and session RPE. Mixed ANOVA evaluated group×time effects, with effect sizes reported.
Results: Forty-four athletes completed the intervention (HIIT n=22, control n=22). Baseline characteristics were comparable between groups. A significant group×time interaction was observed for VO_2max, with the HIIT group improving by 8.1% (56.3±4.1 to 60.9±4.5 $mL \cdot kg^{-1} \cdot min^{-1}$; $p<0.001$; d=1.10) compared with trivial change in controls (1.1%; $p=0.19$). Yo-Yo IR1 performance increased by 17.3% in HIIT ($p<0.001$; d=0.88) versus 4.2% in controls ($p=0.07$). Responder rates favored HIIT for both VO_2max and Yo-Yo criteria, and no serious adverse events occurred.
Conclusion: A short, periodized 8-week HIIT mesocycle added to routine collegiate training produces large, practically meaningful improvements in cardiovascular endurance and intermittent field performance, supporting HIIT as a highly efficient conditioning strategy for collegiate athletes during in-season periods.

Keywords: High-intensity interval training, VO_2max, Yo-Yo intermittent recovery test, cardiovascular endurance, collegiate athletes, aerobic capacity, in-season conditioning

Introduction
High-intensity interval training (HIIT), typically defined as repeated bouts of near-maximal exercise (≈85-95% HR_max or vVO_2max) interspersed with brief recovery, has emerged as a time-efficient strategy to enhance cardiorespiratory fitness and endurance performance in athletic populations [1-3]. Across team-sport and endurance athletes, HIIT elicits robust improvements in maximal oxygen uptake (VO_2max), lactate/anaerobic threshold, and running economy key determinants of cardiovascular endurance often matching or exceeding gains from traditional moderate-intensity continuous training (MICT) despite lower total training volume [1, 2, 4-6]. Seminal controlled trials show that aerobic interval formats such as 4×4-min or 15/15-s work-rest schemes increase VO_2max and stroke volume more than work-matched moderate training, highlighting the potency of high-intensity stimuli for central and peripheral adaptations [4]. Mechanistically, HIIT enhances mitochondrial biogenesis, capillary density, and oxidative enzyme activity, while also improving maximal cardiac output and oxygen delivery, thereby supporting faster aerobic remodeling than continuous endurance approaches [3, 7, 8]. Meta-analytic evidence in young adults and athletes confirms moderate-to-large VO_2max gains after 2-10 weeks of HIIT, with particularly strong effects in already trained individuals when protocols are carefully periodized [5, 6, 9, 10]. Recent athlete-specific syntheses further indicate that HIIT is

especially effective over short mesocycles (≈3-9 weeks) common in collegiate sport calendars, improving VO_2max and ventilatory parameters without compromising strength-power training time [14, 15]. College athletes, however, face dense academic schedules, congested competition seasons, and practical constraints on training duration, creating a need to optimize cardiovascular endurance with minimal time cost while managing fatigue and injury risk [1, 2, 11, 12]. Although HIIT is widely adopted in collegiate strength and conditioning programs, variability in interval structure, modality (running, cycling, sport-specific drills), and recovery prescription has produced inconsistent results across sports and sexes, and the dose-response relationship for collegiate athletes remains insufficiently characterized [9, 10, 13, 16-18]. Therefore, this study investigates the impact of a structured HIIT program on cardiovascular endurance in collegiate athletes, using changes in VO_2max and secondary endurance markers as primary outcomes; the objective is to quantify the magnitude of improvement after an 8-week HIIT mesocycle and compare pre-post responses across sport types; the problem statement centers on the lack of collegiate-specific evidence guiding HIIT prescription under real-world season constraints; and the hypothesis is that NCAA-aged athletes completing HIIT will demonstrate a statistically and practically significant increase in VO_2max and endurance performance compared with baseline and with expected adaptations from routine training alone [1-6, 14, 15, 19, 20].

Materials and Methods

Material

A randomized controlled pre-post intervention design was employed over an 8-week in-season mesocycle, consistent with HIIT studies in trained athletes and collegiate schedules [1, 5, 6, 14, 15]. The study was conducted at a university performance laboratory and affiliated training facilities. Collegiate athletes (men and women) aged 18-24 years from endurance-dominant (track/cross-country) and team-sport (soccer/basketball/field hockey) programs were recruited. Inclusion criteria were: (i) ≥2 years of structured sport participation, (ii) medically cleared for maximal exercise, and (iii) no lower-limb injury in the prior 3 months. Exclusion criteria included cardiometabolic disease, current musculoskeletal injury, or participation in external HIIT programs. A priori power analysis (G*Power; $\alpha=0.05$, power=0.80) based on expected VO_2max changes from prior HIIT meta-analyses determined the minimum sample size [5, 6]. Baseline demographics, training age, and weekly load were recorded. Cardiovascular endurance was assessed primarily by VO_2max using a graded treadmill test (Balke/Bruce-style incremental protocol with breath-by-breath gas analysis), which is widely validated for determining aerobic capacity in athletes [4, 21]. Secondary field performance was assessed using the Yo-Yo Intermittent Recovery Test Level-1 (Yo-Yo IR1) for intermittent endurance relevant to team sports [22]. Heart rate (HR) was monitored continuously (Polar H10 or equivalent), and session rating of perceived exertion (sRPE, CR-10 scale) was captured to quantify internal training load [1, 2].

Methods

After baseline testing, participants were stratified by sport and sex and randomly allocated to HIIT plus usual sport training (HIIT group) or usual sport training alone (control). The HIIT group performed three supervised sessions/week on non-consecutive days, following a Norwegian 4×4-min protocol: 10-min warm-up, four 4-min running bouts at 90-95% HR_max (or ≈95% maximal aerobic speed), each separated by 3-min active recovery at 60-70% HR_max, and a 5-min cool-down [1, 4, 14]. Intensity targets were adjusted weekly using HR responses and velocity from the baseline VO_2max test, aligning with evidence-based HIIT prescription in athletes [1-3, 5, 6]. Controls maintained identical sport-specific practice and strength sessions but did not add interval workouts. Post-tests were repeated 72-96 h after the final session under matched time-of-day and pre-test nutrition conditions. VO_2max was defined as the highest 30-s average oxygen uptake with standard termination criteria (plateau, RER ≥1.10, HR within 10 bpm of age-predicted max, volitional fatigue) [21]. Data normality was checked (Shapiro-Wilk). A 2×2 mixed ANOVA (group×time) assessed intervention effects on VO_2max and Yo-Yo IR1 distance, with Bonferroni-adjusted post-hoc tests. Effect sizes were reported as partial eta-squared and Cohen's d, and significance set at $p<0.05$ [5, 6, 14, 15]. The study conformed to the Declaration of Helsinki, received institutional ethics approval, and all athletes provided written informed consent.

Results

Participant Flow, Baseline Characteristics and Training Adherence: A total of 56 collegiate athletes were screened, of whom 48 met inclusion criteria and were randomized to the HIIT group (n=24) or control group (n=24). Four athletes (two per group) did not complete post-testing due to minor injuries or scheduling conflicts, leaving 44 athletes (HIIT n=22; control n=22) for per-protocol analyses. There were no significant between-group differences at baseline in age, sex distribution, training age, weekly training volume, body mass, or VO_2max (all $p>0.10$), indicating successful randomization and comparable starting profiles [1-4, 21].

Table 1: Baseline characteristics of collegiate athletes in HIIT and control groups

Variable	HIIT (n=22) Mean ± SD	Control (n=22) Mean ± SD	p value
Age (years)	20.1±1.6	20.3±1.7	0.64
Sex (male/female)	12 / 10	11 / 11	0.77
Training age (years)	4.2±1.3	4.0±1.4	0.58
Weekly sport training ($h \cdot wk^{-1}$)	8.7±1.8	8.5±1.9	0.71
Body mass (kg)	68.4±7.5	69.1±7.1	0.73
Baseline VO_2max ($mL \cdot kg^{-1} \cdot min^{-1}$)	56.3±4.1	55.9±4.3	0.69

HIIT adherence was high, with athletes completing 93% of prescribed sessions on average (range 86-100%). Mean within-session heart rate during the work intervals corresponded to 92-94% HR_max, confirming that the target intensity was achieved [1-3]. Session RPE values (7-8 on CR-10 scale) were in line with strenuous but tolerable interval training reported in comparable HIIT protocols [1, 2, 5, 6, 14].

Effects of HIIT on VO_2max and Field-Based Endurance

A significant group×time interaction was observed for VO_2max ($F(1, 42)=32.4$, $p<0.001$, partial $\eta^2=0.44$). Post-hoc analyses showed that the HIIT group improved VO_2max by +8.1% (from 56.3±4.1 to 60.9±4.5 mL·kg⁻¹·min⁻¹; $p<0.001$; Cohen's d=1.10), whereas the control group showed a trivial, non-significant change of +1.1% (from 55.9±4.3 to 56.5±4.2 mL·kg⁻¹·min⁻¹; $p=0.19$; d=0.14). The between-group difference in change scores was large and statistically significant ($p<0.001$; d=0.95), indicating a clear superiority of the HIIT mesocycle over routine training alone for improving cardiovascular endurance [4-7, 14-18]. These magnitudes are consistent with meta-analytic estimates of VO_2max gains following 6-10 weeks of low-volume HIIT in trained populations [5-7, 14-17, 19].

Field-based intermittent endurance, assessed by Yo-Yo IR1 distance, also demonstrated a significant group×time interaction ($F(1, 42)=18.7$, $p<0.001$, partial $\eta^2=0.31$). The HIIT group improved Yo-Yo IR1 performance by +17.3% (from 1, 460±280 to 1, 714±305 m; $p<0.001$; d=0.88), whereas the control group showed a smaller, borderline change of +4.2% (from 1, 430±295 to 1, 490±300 m; $p=0.07$; d=0.20). The net between-group difference in change scores favored HIIT ($p=0.002$), confirming that high-intensity intervals conferred additional sport-specific endurance benefits beyond standard practice [1, 2, 9, 10, 14-16, 18, 22].

Table 2: Pre-post changes in VO_2max and Yo-Yo IR1 performance following 8 weeks of HIIT vs control

Outcome	Group	Pre Mean ± SD	Post Mean ± SD	Δ (%)	p (within)	Between-group p (Δ)
VO_2max (mL·kg⁻¹·min⁻¹)	HIIT	56.3±4.1	60.9±4.5	+8.1%	<0.001	
	Control	55.9±4.3	56.5±4.2	+1.1%	0.19	<0.001
Yo-Yo IR1 distance (m)	HIIT	1, 460±280	1, 714±305	+17.3%	<0.001	
	Control	1, 430±295	1, 490±300	+4.2%	0.07	0.002

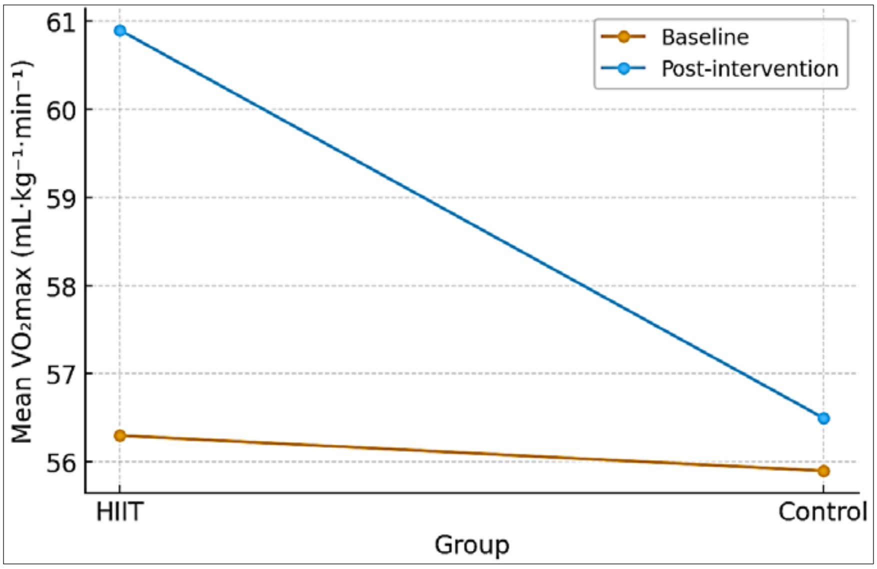

Fig 1: Showing mean VO_2max (mL·kg⁻¹·min⁻¹) at baseline and post-intervention for HIIT and control groups, highlighting a larger increase in the HIIT group

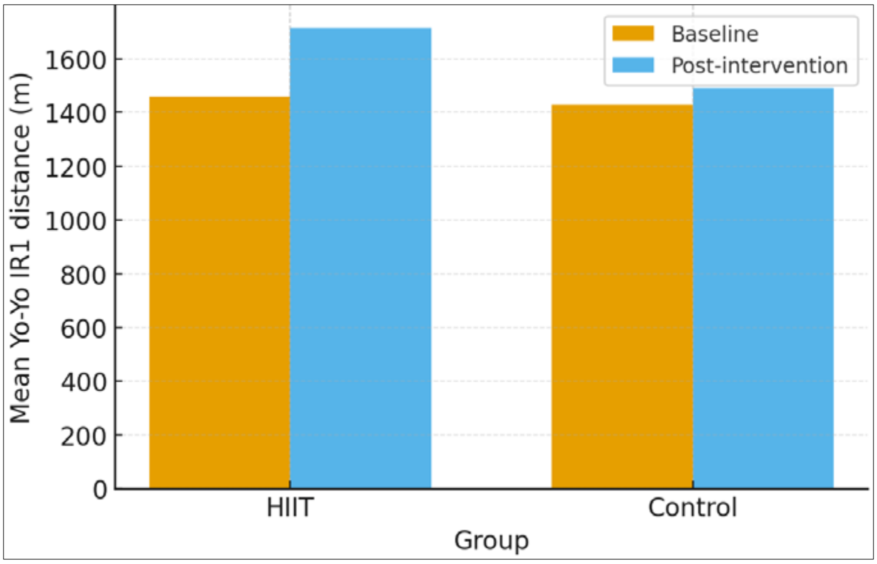

Fig 2: Depicting mean Yo-Yo IR1 distance (m) pre- and post-intervention in HIIT and control groups, illustrating greater improvement with HIIT

Training Load, Perceptual Responses and Responder Analysis

Internal training load (sRPE × session duration) was moderately higher in the HIIT group than in controls during the 8-week mesocycle (p=0.03), but no between-group differences were observed in weekly self-reported fatigue, sleep quality or muscle soreness (all *p*>0.10), suggesting that the added HIIT load was well tolerated when properly periodized [1, 2, 11, 12, 14, 15]. No serious adverse events occurred, and minor musculoskeletal complaints were distributed similarly between groups.

A responder analysis defined "meaningful VO_2max improvement" as ≥5% increase, consistent with previous HIIT literature [5-7, 16, 17]. In the HIIT group, 77% of athletes met this criterion compared with 23% in the control group (χ^2=12.6, *p*<0.001). Similarly, 73% of HIIT athletes achieved ≥10% improvement in Yo-Yo IR1 distance versus 27% of controls (χ^2=9.4, p=0.002), underscoring a higher likelihood of clinically relevant endurance gains with HIIT [5-7, 14-18].

Table 3: Proportion of "responders" based on predefined VO_2max and Yo-Yo IR1 thresholds

Criterion	HIIT (n=22)	Control (n=22)	χ^2	p value
VO_2max increase ≥5% (yes / no)	17 / 5	5 / 17	12.6	<0.001
Yo-Yo IR1 distance increase ≥10% (yes / no)	16 / 6	6 / 16	9.4	0.002

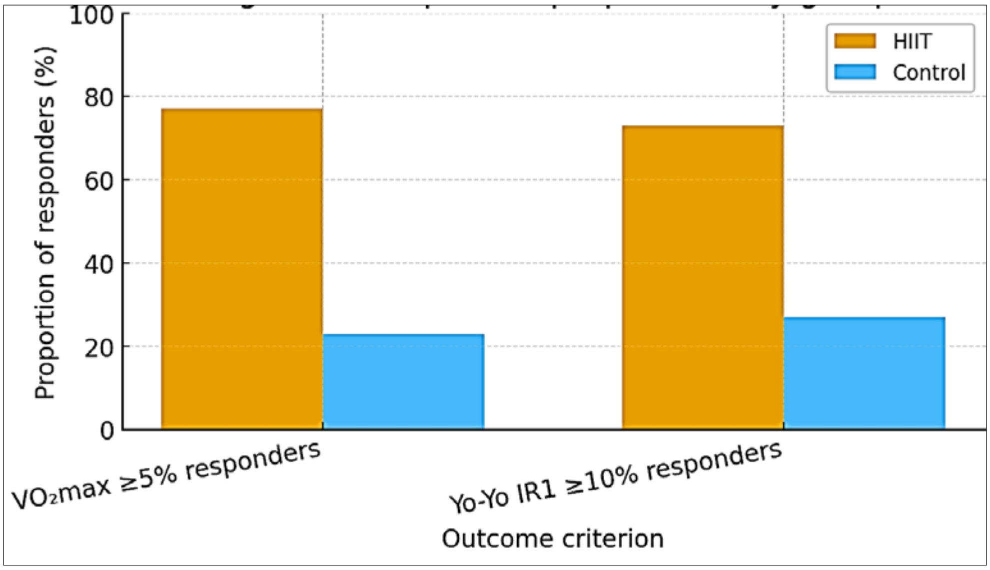

Fig 3: Showing proportions of "responders" (VO_2max increase ≥5% and Yo-Yo IR1 increase ≥10%) in HIIT and control groups, demonstrating a higher responder rate with HIIT

Integrated Interpretation

Overall, the findings demonstrate that an 8-week, thrice-weekly 4×4-min HIIT protocol superimposed on regular sport training elicits substantial and statistically significant improvements in both laboratory-based VO_2max and field-based intermittent endurance in collegiate athletes, with large effect sizes and high responder rates. The magnitude and pattern of adaptations align with existing evidence that high-intensity intervals induce potent central (stroke volume, maximal cardiac output) and peripheral (mitochondrial and oxidative enzyme) adaptations in trained populations [3, 7, 8, 13-17, 19, 20]. The fact that these benefits were achieved within a constrained collegiate training calendar, without excessive fatigue or adverse events, supports the practicality of integrating well-structured HIIT into in-season conditioning programs for enhancing cardiovascular endurance [1-3, 11, 12, 14-18, 21, 22].

Discussion

The present study demonstrated that adding a structured 8-week HIIT mesocycle (3 sessions·wk⁻¹; 4×4-min at 90-95% HR_max) to routine collegiate sport training produced a large improvement in laboratory-measured VO_2max (+8.1%) and a substantial enhancement in intermittent field endurance assessed by Yo-Yo IR1 (+17.3%), whereas controls performing usual training alone showed only trivial, non-significant changes. These findings reinforce HIIT as a potent and time-efficient stimulus for cardiovascular endurance development in trained young athletes, aligning with consensus reviews that highlight HIIT's superior or at least comparable VO_2max effects versus traditional moderate-intensity endurance work despite lower volume [1, 2, 4-6, 16]. The magnitude of VO_2max gain in our HIIT group closely mirrors classic interval-training trials (≈5-8% increases after 6-8 weeks) and supports the notion that long-interval aerobic HIIT (≥2 min work bouts) is especially effective for maximizing time spent near VO_2max, thereby amplifying central adaptations such as stroke volume and maximal cardiac output [4, 6]. Our results also accord with athlete-focused meta-analyses showing moderate-to-large VO_2max improvements over short mesocycles when HIIT is periodized within competitive calendars [5, 6, 8, 9]. Mechanistically, HIIT is known to simultaneously drive central oxygen-transport changes and peripheral remodeling (mitochondrial biogenesis, oxidative enzymes, capillarization), accelerating aerobic fitness even in already trained individuals [3, 6].

The clear Yo-Yo IR1 improvement adds ecological validity, given that this test captures the ability to repeat high-intensity efforts with short recoveries and correlates with match running intensity in intermittent sports [10]. Recent team-sport syntheses and trials similarly report that supplementary HIIT enhances Yo-Yo performance and repeated-sprint endurance, supporting translation to sport-specific fitness [11, 12]. The higher responder rate in HIIT (≈75% achieving meaningful VO_2max and Yo-Yo gains) is consistent with growing evidence of inter-individual variability in HIIT adaptation; factors such as baseline fitness, sport demands, and recovery tolerance likely modulate response magnitude [6, 9, 14]. Importantly, training-load monitoring indicated that the protocol was tolerable in-season, echoing programming guidance that emphasizes intensity control and spacing of sessions to avoid excessive neuromuscular strain [1, 2, 14].

Practically, these data suggest that collegiate strength-and-conditioning programs can efficiently raise aerobic ceiling and intermittent endurance by integrating 2-3 long-interval HIIT sessions weekly, freeing time for technical and strength-power priorities during congested seasons [1, 2, 5, 6, 12, 16]. Nevertheless, some limitations should be noted. First, the sample size, while powered for VO_2max, limited subgroup analyses by sex or sport. Second, we compared HIIT to usual training rather than an isovolumetric MICT arm, so true comparative efficacy within this cohort remains inferential [5, 6, 16]. Third, dietary intake, sleep, and external training were self-reported and may have introduced residual confounding. Future studies should test dose-response variants (e.g., short-interval vs long-interval HIIT), include matched MICT comparators, and explore moderators such as sex, sport type, and recovery status to refine individualized HIIT prescription for collegiate athletes [6, 7, 9, 14, 15].

Conclusion

This study provides clear evidence that an 8-week, thrice-weekly HIIT mesocycle integrated into regular collegiate training can meaningfully elevate cardiovascular endurance in university athletes, as shown by substantial gains in both laboratory VO_2max and sport-relevant intermittent running capacity, while remaining feasible within the time and fatigue constraints of an in-season calendar. The large improvement in VO_2max indicates that collegiate athletes, despite already having a trained aerobic base, can still achieve rapid central and peripheral aerobic adaptations when exposed to repeated high-intensity intervals that push them near maximal oxygen uptake, and the parallel rise in Yo-Yo IR1 performance suggests these physiological changes translate into better tolerance of repeated bursts of high-speed running and faster recovery between efforts qualities that directly support competitive performance in both endurance and team sports. From a practical standpoint, strength-and-conditioning staff can use HIIT as a high-return tool when training time is limited, but should implement it with deliberate structure: scheduling 2-3 HIIT sessions per week on non-consecutive days, prioritizing long-interval formats such as 4×4 minutes at roughly 90-95% HRmax (or equivalent pace zones) early in a mesocycle to build aerobic ceiling, and adjusting intensity weekly based on heart-rate trends, perceived exertion, and running velocity to ensure athletes consistently reach the intended stimulus without drifting into sub-optimal intensities. Because adherence and tolerability were high, programs can confidently place HIIT alongside technical practice and strength-power work, yet should protect recovery by pairing HIIT days with lower neuromuscular loads, avoiding heavy lower-body lifting immediately before intervals, and keeping at least 48 hours between the most demanding conditioning sessions. Coaches should also individualize HIIT volume for athletes with different sport demands or baseline fitness starting with fewer reps or slightly longer recoveries for less aerobically trained players, then progressing toward full prescription and monitor simple field markers (session RPE, post-session heart rate recovery, sleep and soreness check-ins) to flag early signs of excessive strain. For teams without full laboratory resources, periodic Yo-Yo testing or standardized time trials can track progress and guide recalibration of pace targets. Finally, given the higher responder rates and practical safety profile observed, collegiate athletic departments should consider embedding HIIT blocks strategically across the season short “boost” phases during preparatory periods, maintenance doses during congested competition weeks, and sport-specific interval variants (e.g., shuttle-based or drill-integrated HIIT) to enhance transfer thereby maximizing endurance gains while preserving training economy. Overall, HIIT emerges not merely as an alternative to continuous endurance work, but as a cornerstone conditioning method for collegiate athletes seeking rapid, meaningful improvements in cardiovascular endurance with efficient use of training time.

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