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Research article

Comparing The Effects of Singles vs. Doubles High-Intensity On-Court Tennis Training and Regular High-Intensity Interval Training on Aerobic and Anaerobic Performance Adaptations: A Randomized, Parallel-Controlled Study

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Abstract

Adopting specificity in practice, combined with conditioning, can be an especially effective approach to optimizing training for tennis players. However, little is known about the use of different tennis formats in conditioning drills. The purpose of this study was to compare the effects of singles versus doubles high-intensity interval training (HIIT) tennis training on the aerobic and anaerobic performance of young tennis players, while also evaluating both formats against traditional off-court HIIT training. A randomized parallel controlled study was conducted with 48 male youth tennis players (16.8 ± 0.8 years). The intervention lasted 6 weeks and was carried out twice a week, with singles and doubles HIIT performed in match-play format without serving, while regular HIIT consisted of running (regHIIT). Measurements were taken at baseline and post-intervention, including the Wingate Anaerobic Test (to determine peak and mean power output and decrement), the Hit and Turn Tennis Test (to estimate maximal oxygen uptake, VO_{2max}), and the 30-15 Intermittent Fitness Test (V_{IFT}). Using ANCOVA, the Group effect was significant for Wingate peak power. Singles-HIIT exceeded doubles-HIIT (Δ = 0.85 W·kg⁻¹, 95% CI 0.63 - 1.08; $p < 0.001$, Holm), regHIIT (Δ = 0.80 W·kg⁻¹, 0.58 - 1.02; $p < 0.001$), and control (Δ = 1.79 W·kg⁻¹, 1.57 - 2.02; $p < 0.001$); doubles-HIIT and regHIIT did not differ ($p = 0.620$). For mean power, singles-HIIT was higher than doubles-HIIT (Δ = 1.07 W·kg⁻¹, 0.80 - 1.34; $p < 0.001$), regHIIT (Δ = 1.00 W·kg⁻¹, 0.74 - 1.27; $p < 0.001$), and control (Δ = 1.60 W·kg⁻¹, 1.33 - 1.87; $p < 0.001$); both doubles-HIIT and regHIIT exceeded control (Δ = 0.53 - 0.60 W·kg⁻¹; both $p < 0.001$). VO_{2max} and VIFT improved similarly across all HIIT formats versus control (VO_2max Δ = 2.10 - 2.13 mL·kg⁻¹·min⁻¹; VIFT Δ = 0.98 - 1.01 km·h⁻¹; all $p < 0.001$), with no differences among HIIT formats (all $p \geq 0.90$). In this randomized trial, singles-HIIT produced greater gains in anaerobic performance—showing higher adjusted post-test Wingate peak and mean power—than doubles-HIIT or regHIIT, under the present unmatched-intensity conditions. Aerobic adaptations (VO_{2max} and VIFT) improved similarly across all HIIT formats and were superior to control. Therefore, singles-HIIT may be preferable when the primary goal is to enhance anaerobic power, whereas any of the three formats can be effectively used for aerobic conditioning, depending on logistical and sport-specific considerations. These inferences apply to the present on-court HIIT protocol in youth players and should be generalized cautiously to other sexes, ages, training levels, and court surfaces.

Key words: Game-based tennis, interval training, aerobic training, youth, physical fitness.

Introduction

Tennis match-play is characterized by intermittent efforts, with short rallies (3.4 - 8.2 seconds) interspersed with rest periods (Fernandez-Fernandez et al., 2007; Zagatto et al., 2010). Physiological responses during matches include elevated heart rates (161 - 164 bpm) and moderate blood lactate concentrations (1.8 - 2.2 mmol/L) (Zagatto et al., 2010; Kilit et al., 2016). The aerobic system is the primary energy source, with the phosphagen system crucial during efforts (Zagatto et al., 2010). Match characteristics such as rally duration, strokes per rally, and changes of direction correlate positively with physiological responses (Fernandez-Fernandez et al., 2007). Prolonged match-play can lead to fatigue, manifesting as physiological, neuromuscular, and psychological perturbations (Reid et al., 2007). However, players may adjust their game strategy to compensate for physiological deterioration (Reid and Duffield, 2014). Recent evidence on short-term recovery patterns in young tennis players demonstrated that both heart rate and oxygen uptake substantially recover within the first 25 s following a rally, emphasizing the physiological relevance of the 25-s rule between points (Morais et al., 2023). These findings highlight the importance of tennis-specific aerobic endurance training to meet match demands.

Research on physiological intensities in youth tennis reveals a predominant focus on low-to-moderate intensity training, which does not align with the intense demands experiencing in match (Moreira et al., 2016). Elite young players spend the majority of their training time in heart rate zones 1 and 2, with only about 10% in high-intensity zone 3 (Moreira et al., 2016; Michel et al., 2022). Thus, it is necessary to introduce specific training formats that create intensified periods aimed at developing both aerobic and anaerobic capacities, aligning with the demands of match play. Regimens as high-intensity intermittent training (HIIT) sessions can achieve average heart rates above 90% HRmax, providing sufficient stimulus for developing maximal aerobic power (Pialoux et al., 2015). These regimens can be targeted through more analytical, running-based drills or by strategically manipulating training scenarios while preserving key aspects of match play.

HIIT has significant physiological impacts on tennis players, improving aerobic capacity and tennis performance (Durmuş et al., 2023). Both on-court and off-court HIIT sessions can achieve heart rates above 90% HRmax, suitable for developing maximal aerobic power (Pialoux et al., 2015). HIIT and on-court tennis training (OTT) show similar improvements in maximal oxygen uptake (VO_{2max}), jumping, and sprinting performance (Kilit and Arslan, 2019). However, OTT can be more interesting for enhanc-

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ing specific technical skills, while HIIT can be more interesting for speed-based conditioning (Kilit and Arslan, 2019). OTT interval training elicits equivalent physiological responses to off-court running intervals, making it a time-efficient alternative for improving cardiorespiratory fitness (Fernandez-Fernandez et al., 2011). Recent evidence demonstrated that a structured OTT program can significantly enhance both technical and physical performance indicators, including International Tennis Number (ITN) scores, VO_{2max}, and change-of-direction ability in young players (Morais et al., 2024b). Despite these benefits, OTT can be affected by fatigue, leading to a decline in stroke velocity and accuracy, especially during HIIT sessions (Pialoux et al., 2015). This can ultimately result in more balls going out and a decrease in exercise intensity.

Another way to adjust intensity is through the playing format. For example, playing singles (1v1) or doubles (2v2) can influence the intensity experienced in HIIT sessions. Recent research has highlighted that doubles tennis differs substantially from singles in structural, temporal, and tactical aspects. Compared with singles, doubles matches involve shorter rallies, fewer strokes per point, and greater emphasis on serve and return effectiveness (Martínez-Gallego et al., 2020). Moreover, the time structure of doubles competition presents lower work-to-rest ratios and shorter point durations, especially among experienced pairs whose coordination allows them to finish points more efficiently (Martínez-Gallego et al., 2021). Historically, the tactical patterns of doubles have evolved markedly; over the past two decades, serve-and-volley frequency has decreased while baseline exchanges and varied return positions have increased, reflecting broader changes in the modern doubles game (Raasch et al., 2025). These contextual distinctions are critical when comparing the physiological and performance demands of singles, doubles, and off-court high-intensity training formats.

Although there are no direct comparisons in tennis, studies on beach tennis and paddle tennis suggest that singles generally impose higher physiological demands—reflected in heart rate responses, perceived effort, and blood lactate levels—compared to doubles (Armstrong et al., 2023; Ferrari et al., 2023; Jung et al., 2024). These findings suggest that different playing formats may elicit distinct internal loads, which could translate into specific aerobic and anaerobic adaptations over time.

However, in tennis, the extent to which singles- and doubles-based HIIT drills differ in their training stimulus and performance outcomes remains unknown. Specifically, no studies have examined whether the greater physiological demands of singles play produce superior improvements in aerobic capacity or anaerobic power, compared with doubles or traditional off-court HIIT.

Addressing this gap is practically important, as optimizing OTT sessions can make them as effective as off-court HIIT while maintaining sport specificity, tactical relevance, and player motivation. Clarifying how training format influences adaptations would help coaches select the most effective HIIT structure for developing targeted performance qualities.

Therefore, the purpose of this study was to compare the effects of singles-based, doubles-based, and running-based (regHIIT) tennis HIIT programs on both aerobic (VO_{2max}, VIFT) and anaerobic (peak and mean power, fatigue index) performance in competitive youth tennis players. It was hypothesized that all HIIT formats would improve both aerobic and anaerobic performance, but that singles-HIIT, due to its greater individual work demands, would result in larger anaerobic gains than doubles- or running-based HIIT.

Methods

Experimental approach to the problem

A randomized, parallel, controlled design was implemented with three intervention groups—singles-HIIT, doubles-HIIT, and regular running-based (off-court) (regHIIT)—and one control group that continued their regular on-court practice without any additional conditioning. The intervention period lasted six weeks, after which groups were compared on the primary and secondary outcomes.

All assessments were performed twice: (i) baseline, prior to randomization and group allocation, and (ii) post-intervention (after six weeks). Randomization used a simple method with a 1:1:1:1 allocation ratio, giving all participants an equal chance of assignment to any group. An investigator not involved in recruitment, testing, or training delivery generated the assignment codes and prepared sequentially numbered, opaque, sealed envelopes. Envelopes were opened only after each participant completed all baseline tests, ensuring allocation concealment. Participants were not permitted to switch groups after allocation. Outcome evaluators (pre- and post-tests) were blinded to group assignment; coaches delivering the interventions could not be blinded for practical reasons.

Participants

The primary endpoint for sample-size planning was Wingate 30-s peak power ($W \cdot kg^{-1}$). Given the randomized four-arm parallel design (singles-HIIT, doubles-HIIT, regHIIT, control) with pre/post measurements, we specified the confirmatory analysis as an ANCOVA on post-intervention peak power, with Group (4 levels) as the fixed factor and baseline peak power as a covariate (recommended for RCTs to reduce residual variance). We planned for a moderate between-group effect (Cohen's $f = 0.25$ - 0.30, roughly $d \approx 0.50$ - 0.60) based on randomized athlete studies showing meaningful—but not extreme—improvements in Wingate peak/mean power after HIIT or court-based intervals (e.g., tennis and racket-sport trials, and a meta-analytic benchmark for anaerobic outcomes) (Fernandez-Fernandez et al., 2012; Weston et al., 2014; Ko et al., 2021). We set $\alpha = 0.05$ (two-sided), power = 0.80 (with 0.90 examined in sensitivity analyses), equal allocation (1:1:1:1), and assumed a baseline–post correlation $r = 0.70$ for Wingate peak power (typical test–retest range in trained athletes). For context with our cohort, the baseline pooled SD across groups for Wingate peak power was ≈0.65 $W \cdot kg^{-1}$ (from the observed pre-test SDs: 0.51, 0.73, 0.66, 0.67 $W \cdot kg^{-1}$; $n = 12$ per group). Under these assumptions in an ANCOVA framework, the required total sample for 80% power is $N = 92$ (≈23 per group) for $f = 0.25$ and $N =$

62 (≈16 per group) for f = 0.30; at 90% power the corresponding totals are N = 124 (≈31 per group) and N = 82 (≈21 per group), respectively. A sensitivity analysis indicates that with the realized N = 48 (≈12 per group) the study has ~80% power to detect a minimum between-group effect of f ≈ 0.33 (≈ d ≈ 0.66) after baseline adjustment. Calculations were performed in G*Power v3.1.

Participants were eligible for inclusion if they were youth tennis players aged 16 to 18, had been actively engaged in competitive training for over three years, attended both pre- and post-intervention assessment sessions, and adhered to at least 90% of the intervention sessions. Exclusion criteria included any pre-existing cardiovascular or musculoskeletal conditions that would limit participation in strenuous exercise, current use of performance-enhancing drugs, or a history of significant injury within the past six months that would impede their ability to perform HIIT. Critically, participants were excluded if they were concurrently engaged in any additional fitness conditioning programs outside of the HIIT intervention provided in this study, to isolate the effects of the experimental treatment.

Youth tennis players were recruited from local tennis clubs and academies. A convenience sampling method was employed, targeting athletes who met the inclusion criteria. This approach allowed for efficient recruitment of a sample of competitive youth tennis players willing to participate in the HIIT intervention.

A total of 48 youth male tennis players (Figure 1) were recruited and randomly assigned to one of four groups: singles HIIT (n = 12), doubles HIIT (n = 12), regular HIIT (n = 12), and a control group (n = 12). The participants' mean age was 16.8 ± 0.8 years, with an average training experience of 5.0 ± 0.9 years. Anthropometric measures revealed an average height of 176.6 ± 3.2 cm, an average weight of 68.8 ± 3.2 kg, and an average body mass index of 22.0 ± 0.5 kg/m^2. Competitive level was characterized using the International Tennis Number (ITN) format conducted during baseline week by two certified coaches who were blinded to group allocation. The standard stroke-based ITN drills (groundstroke consistency/depth, serve, and return) were administered per ITF guidelines, with the better of two trials retained. Inter-rater agreement on the categorical ITN call (3, 4, 5, etc.) was 94%, and disagreements were resolved by consensus immediately after testing. The median ITN was 4 (IQR: 3 - 5), consistent with advanced/intermediate-advanced non-elite competitors; 0% held ATP/WTA rankings and ~70% entered regional federation events during the study period. ITN distributions did not differ between groups (median [IQR]: ITN 4 [3 - 5] in each group; Mann–Whitney U, p = 0.78).

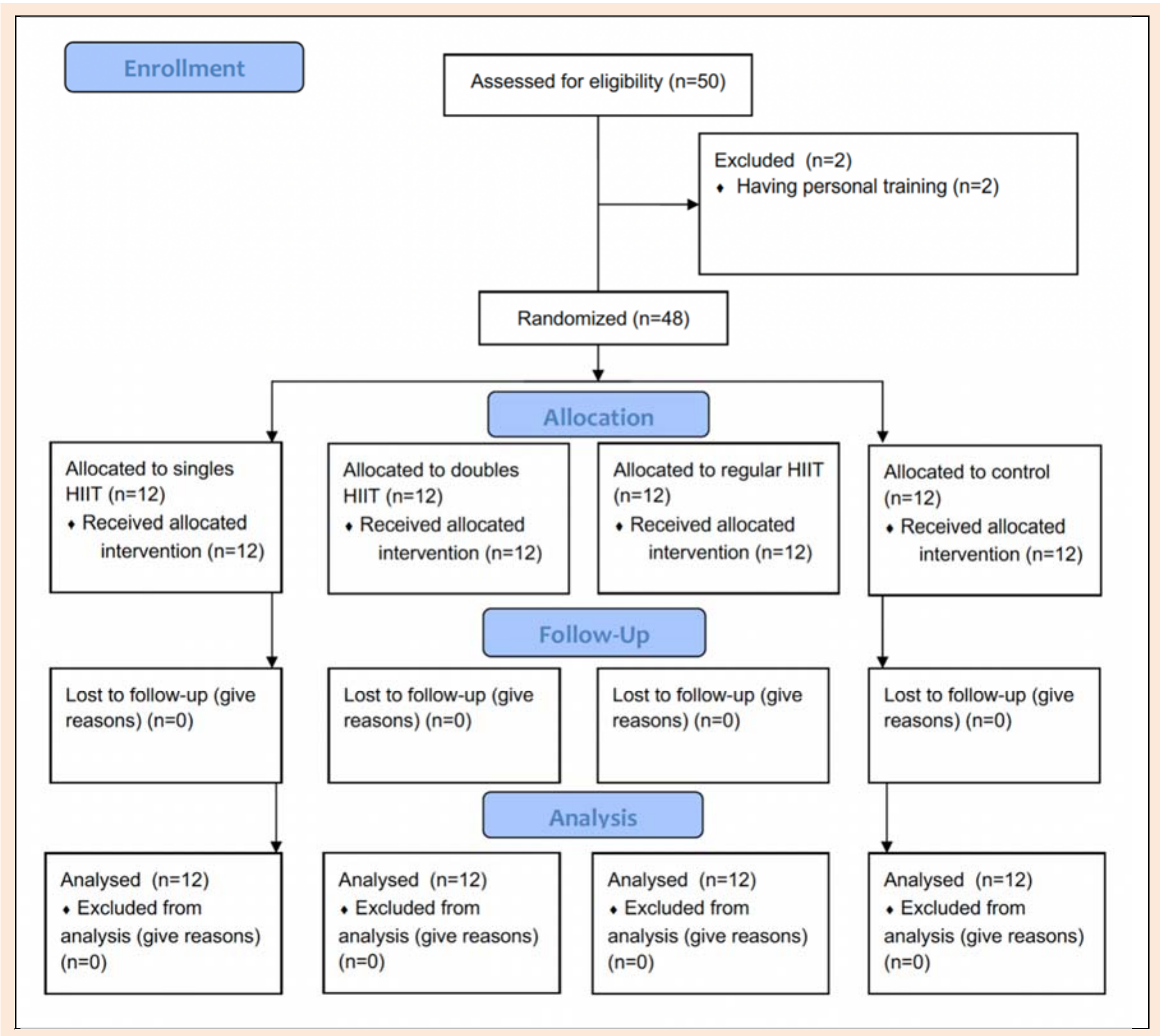

Figure 1. Flowchart depicting participant progression through the experimental phases.

Participant attendance was recorded at every training session. Adherence was defined as the percentage of prescribed HIIT sessions completed out of the total scheduled sessions (n = 12). Overall adherence was high across all groups: singles-HIIT = 94.4 ± 6.2%, doubles-HIIT = 95.8 ± 5.4%, and regHIIT = 96.5 ± 4.8%. The control group continued their regular tennis training and completed all scheduled academy sessions. Minor absences were mainly due to academic obligations. No training-related injuries or adverse events were reported during the intervention or testing periods, and all participants completed post-intervention assessments.

For this study involving youth athletes, ethical procedures were rigorously followed. Informed consent was secured from both the athletes and their legal guardians, detailing the study's objectives and methods. Furthermore, all data collected was anonymized to guarantee participant confidentiality and protect their identities. This study was conducted with the approval of the Sichuan Normal University and code number [2025L50026] and adhered to the principles outlined in the Declaration of Helsinki.

Training interventions

In their regular routines, players participated in four on-court tennis training sessions per week, held on Mondays, Tuesdays, Thursdays, and Fridays. Their typical on-court training sessions included a warm-up, followed by rally-based drills such as cross-court and down-the-line hitting to develop consistency and shot placement. They then focused on specific techniques, including serve and return practice, volleys, and approach shots, emphasizing precision and power. Tactical drills followed, concentrating on point construction, movement patterns, and match play scenarios, which were typically conducted at the end of the session. Their regular training sessions lasted between 100 and 120 minutes and were conducted in the afternoon. All on-court training routines were exclusively designed by their coaches as part of the structured programs within their academies.

All intervention sessions (singles-HIIT, doubles-HIIT, and regHIIT) were scheduled in the late afternoon/early evening between 17:00 and 19:00 (local time) on non-consecutive days within a single season (early autumn). Sessions took place on the same hard-court facility. Ambient temperature and relative humidity were recorded before each session with a handheld thermo-hygrometer (Testo 608-H1, Lenzkirch, Germany) and typically ranged between 18 - 22 °C and 45 - 55% relative humidity. Participants were instructed to maintain habitual sleep and diet patterns and to avoid caffeine and strenuous exercise for 24 h before each testing and training session.

In addition to their regular training routines, the experimental groups participated in HIIT sessions, which were conducted at the end of their standard training sessions twice a week (on Mondays and Thursdays). These HIIT sessions were administered by the research team under the supervision of the coaches. The characteristics of the HIIT training are shown in Table 1.

Singles and doubles HIIT were introduced as drills without serving. To facilitate this, one researcher and one assistant were positioned near the baseline of each court. Whenever a rally ended, the researcher or assistant quickly repositioned the ball with their racquets to the half of the court opposite to where the point was won. This process ensured a fast ball repositioning, allowing the game to continue without interruptions. Standard court dimensions for singles and doubles were used, and all matches were played on hard courts. Exercise intensity during the singles- and doubles-based HIIT drills was monitored using post-session rating of perceived exertion (RPE). After each bout, players reported their RPE using the CR-10 scale, aiming for values between 8 and 10. Individual reports were collected and scored in response to the question “How was your workout?”. These RPE values were used solely to represent perceived exercise intensity. Ball frequency (approximately one ball every 2.5 - 3 seconds) and rally duration were standardized to ensure a comparable external load between the singles and doubles HIIT formats.

Singles- and doubles-HIIT were performed as tennis-specific rally drills (no serving). Each “rally” corresponded to 30 - 40 s of continuous play followed by 30 s of passive recovery. Two sets were completed per session, separated by 3 min of passive rest. Each set lasted approximately 4 - 5 min in total. In doubles-HIIT, the rally structure and set duration were identical to singles-HIIT, but each player’s effective work time per rally was reduced because effort was shared between partners, resulting in slightly lower individual external load while maintaining comparable intensity (RPE = 8 - 10).

Running-HIIT (regHIIT) used shuttle runs at 85 - 95% of each player’s individual VIFT with the same work-to-rest pattern and total work duration. Their running pace was regulated by the number of runs required to cover a predetermined distance, which was determined by their test scores. Total effective work time refers to the cumulative active intervals per player per session and excludes inter-set recovery.

The volume of HIIT was consistent across the three experimental groups, as was the progression in volume. During the first two weeks, players completed two HIIT sessions per week, each consisting of 10 - 11 minutes of effective work time (i.e., exercise time excluding rest). In weeks three and four, this increased to 13 minutes per session, and in weeks five and six, to 16 minutes per session, again excluding rest periods. The RPE (i.e., CR10 score taken 30 min post session) was monitored during each session to provide an indicator of intensity relative to the players' efforts.

Measurements

Measurements were taken during the week prior to the start of the intervention and again in the week immediately following its completion. Main measurements were conducted on Monday afternoons, following a 48-hour rest period after the weekend. The assessments took place at the academies, using an indoor space to collect demographic and anthropometric data. Participants then performed a standardized warm-up routine before completing the Wingate Anaerobic Test to assess anaerobic performance. After the test, athletes rested for five minutes. Following the rest period, they completed the Hit and Turn Tennis Test (HTTT), a specific endurance test designed for tennis players.

Table 1. Description of the HIIT training program.

Week	Session	Singles-HIIT (on-court, no serving) Sets × rallies × time per rally	Doubles-HIIT (on-court, no serving) Sets × rallies × time per rally	Running-HIIT (regHIIT, shuttle running at %VIFT) Bouts× time per bout	Total effective work time per player (min)
1	1	2 sets × (6–8 rallies × 30–40 s, 30 s rest between rallies); 3 min rest between sets	2 sets × (6–8 rallies × 30–40 s, 30 s rest between rallies); 3 min rest between sets; players alternate actions within each rally	12 bouts × 30–40 s @ 85% VIFT, 30 s rest between bouts	8
1	2	2 sets × (8–10 rallies × 30–40 s, 30 s rest); 3 min rest between sets	2 sets × (8–10 rallies × 30–40 s, 30 s rest); 3 min rest; shared workload between partners	16 bouts × 30–40 s @ 95% VIFT, 30 s rest	10-11
2	3	2 sets × (6–8 rallies × 30–40 s, 30 s rest); 3 min rest between sets	2 sets × (6–8 rallies × 30–40 s, 30 s rest); 3 min rest; alternate strokes	12 bouts × 30–40 s @ 85% VIFT, 30 s rest	8
2	4	2 sets × (8–10 rallies × 30–40 s, 30 s rest); 3 min rest	2 sets × (8–10 rallies × 30–40 s, 30 s rest); 3 min rest; alternate strokes	16 bouts × 30–40 s @ 95% VIFT, 30 s rest	10-11
3	5	2 sets × (8–10 rallies × 30–40 s, 30 s rest); 3 min rest	2 sets × (8–10 rallies × 30–40 s, 30 s rest); 3 min rest; shared workload	16 bouts × 30–40 s @ 85% VIFT, 30 s rest	10-11
3	6	2 sets × (10–12 rallies × 30–40 s, 30 s rest); 3 min rest	2 sets × (10–12 rallies × 30–40 s, 30 s rest); 3 min rest; shared workload	20 bouts × 30–40 s @ 95% VIFT, 30 s rest	12-13
4	7	2 sets × (8–10 rallies × 30–40 s, 30 s rest); 3 min rest	2 sets × (8–10 rallies × 30–40 s, 30 s rest); 3 min rest; shared workload	16 bouts × 30–40 s @ 85% VIFT, 30 s rest	10-11
4	8	2 sets × (10–12 rallies × 30–40 s, 30 s rest); 3 min rest	2 sets × (10–12 rallies × 30–40 s, 30 s rest); 3 min rest; shared workload	20 bouts × 30–40 s @ 95% VIFT, 30 s rest	12-13
5	9	2 sets × (10–12 rallies × 30–40 s, 30 s rest); 3 min rest	2 sets × (10–12 rallies × 30–40 s, 30 s rest); 3 min rest; shared workload	20 bouts × 30–40 s @ 85% VIFT, 30 s rest	12-13
5	10	2 sets × (12–14 rallies × 30–40 s, 30 s rest); 3 min rest	2 sets × (12–14 rallies × 30–40 s, 30 s rest); 3 min rest; shared workload	24 bouts × 30–40 s @ 95% VIFT, 30 s rest	14-16
6	11	2 sets × (10–12 rallies × 30–40 s, 30 s rest); 3 min rest	2 sets × (10–12 rallies × 30–40 s, 30 s rest); 3 min rest; shared workload	20 bouts × 30–40 s @ 85% VIFT, 30 s rest	12-13
6	12	2 sets × (12–14 rallies × 30–40 s, 30 s rest); 3 min rest	2 sets × (12–14 rallies × 30–40 s, 30 s rest); 3 min rest; shared workload	24 bouts × 30–40 s @ 95% VIFT, 30 s rest	14-16

HIIT: high-intensity interval training; regHIIT: running-based HIIT; VIFT: final velocity at 30-15 intermittent fitness test. Total effective work time per player is the workout time excluding rest periods.

In addition to these two primary outcomes measured on Monday, the 30 - 15 Intermittent Fitness Test was conducted on Thursday, following a 24-hour rest period. This test was included to provide an individual marker for standardizing regular HIIT performance. All participants were already familiar with the Wingate Anaerobic Test, the Hit & Turn Tennis Test (HTTT), and the 30 - 15 Intermittent Fitness Test (VIFT), as these assessments were routinely included in their academies' fitness monitoring programs. Consequently, no additional familiarization sessions were required before baseline testing.

Anthropometric measurements

Height was measured using a calibrated stadiometer (model 213, SECA), with players standing shoeless and upright, heels, buttocks, and the back of their head in contact with the stadiometer, and gaze directed forward. Measurements were recorded to the nearest 0.1 centimeter. Body mass was determined using a calibrated digital scale (model 813, SECA), with players standing shoeless and lightly clothed, distributing their weight evenly. Measurements were recorded to the nearest 0.1 kilogram, and the scale was zeroed before each measurement. Body mass index (BMI) was calculated by dividing the player's body mass in kilograms by the square of their height in meters (BMI = kg/m^2).

Wingate anaerobic test

The Wingate Anaerobic Test was implemented on tennis players using a Monark cycle ergometer (model 894E), ensuring accuracy through prior calibration. The Monark ergometer was mechanically calibrated using a standard 4kg weight to verify the resistance applied by the brake, adhering to the manufacturer's guidelines. Following a brief warm-up, each player performed a 30-second maximal effort sprint against a resistance load calculated based on their body weight. Power output was recorded throughout the test. To determine maximal output, the highest power value achieved during the 30-second sprint was identified. Mean power was calculated by averaging the power output values across the entire 30-second duration. The fatigue index (FI%), representing the degree of fatigue, was calculated using the formula: FI% = ((Peak - Lowest) / Peak) × 100. This data, acquired from the ergometer, was then used to analyze each player's anaerobic power and capacity.

Hit and Turn Tennis Test (HTTT)

The test is a progressively difficult, acoustically controlled on-court fitness assessment, designed to be performed by one or more players simultaneously (Ferrauti et al., 2011). Players are required to execute movements along the baseline, including sidestepping and running, while also simulating forehand and backhand strokes at the doubles court corner (11 meters away). The test consists of 20 levels, with each level progressively decreasing the time allowed per stroke by 0.1 seconds. It starts at 4.9 seconds per stroke in level 1 and reduces to 3.0 seconds by level 20. Each level lasts approximately 47 - 50 seconds, involving 12 - 16 strokes, with 10-second rest periods between levels (Ferrauti et al., 2011).

The player begins at the center of the baseline, holding their racket in a front-facing position. Upon hearing a signal, they turn sideways and run to the designated corner to perform either a forehand or backhand stroke. After striking the ball, the player returns to the center of the court using sidesteps or crossover steps while facing the net. The pattern is repeated by running to the opposite corner and repeating the cycle. Strokes are simulated above cones, and stroke execution is synchronized with the "beep" signals. Researchers monitor the quality of both strokes and footwork.

The test concludes when a player fails to reach the cones within the time limit, or is unable to perform the required footwork or strokes with proper technique. Performance is assessed based on the highest level completed (HTTT), and maximal oxygen uptake (VO_{2max}) is estimated using the following equation derived from test data (Ferrauti et al., 2011): $VO_{2max} = 33.0 + (1.66 \times HTTT)$.

30 - 15 Intermittent Fitness Test

The 30 - 15 Intermittent Fitness Test was conducted on tennis players to assess their indicators to individualize the HIIT training (Buchheit, 2008). Players began running between two lines 20 meters apart, following an audio signal that dictated the pace. The test started at a speed of 8 km/h, with each stage lasting 30 seconds of running followed by 15 seconds of passive recovery. The running speed increased by 0.5 km/h at each subsequent stage. Players continued the test until they could no longer maintain the required pace or reached volitional exhaustion, at which point the last successfully completed stage was recorded. The main outcome obtained from this test was the final velocity (V_{IFT}), which represents the highest running speed the player can maintain while still eliciting maximal oxygen uptake.

Rating of perceived exertion (RPE)

The Borg CR10 scale (Borg, 1998), a numerical rating scale ranging from 0 (nothing at all) to 10 (maximal), was utilized to assess the players' perceived exertion during the intervention sessions. Players were instructed to rate "how hard the exercise felt overall, considering both physical effort and breathing difficulty" during each bout of training and 30-min after the session. Players reported their RPE after each HIIT set, allowing the research team to monitor and regulate exercise intensity in real time across singles-, doubles-, and running-based formats. In addition, a final RPE score was collected 30 minutes after the end of each HIIT session to capture the players' overall perception of exertion. These post-session values were used for subsequent analysis and are presented in the results (see Figure 2). The scale features verbal anchors such as 0 (nothing at all), 0.5 (very, very weak), 1 (very weak), 2 (weak), 3 (moderate), 5 (strong), 7 (very strong), and 10 (maximal), allowing players to reflect their perceived effort accurately regarding the HIIT training. All responses were provided individually using a paper form.

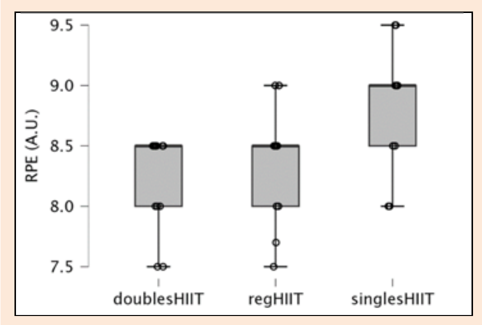

Figure 2. Boxplots depicting ratings of perceived exertion (RPE), assessed using the Borg CR-10 scale 30 minutes after the end of each session, across sessions for each experimental group.

Statistical procedures

The primary endpoint was Wingate 30-s peak power ($W \cdot kg^{-1}$). The confirmatory analysis used an ANCOVA on post-intervention values with Group (singles-HIIT, doubles-HIIT, regHIIT, control) as a fixed factor and the baseline value as a covariate. For secondary outcomes (Wingate mean power, fatigue index, VO_2max, VIFT), the same ANCOVA framework was applied. With only two time points, sphericity is not applicable; a two-way mixed ANOVA (Time × Group) is reported as sensitivity in the Supplement. We report F(df1, df2), p, and partial η^2 for omnibus Group effects, and adjusted pairwise contrasts (estimated at the mean baseline) with Holm-adjusted p and Cohen's d (using the model residual SD). For context, conventional standardized mean differences (Hedges' g), based on the pooled post-test SD, were also computed and reported. Family-wise error was controlled within each outcome (Holm); cross-outcome adjustments were not applied as non-primary outcomes are exploratory. Model assumptions (normality, homoscedasticity) were checked on residuals; bias-corrected bootstrap CIs (5,000 resamples) were used when diagnostics suggested mild deviations. Analyses were performed in SPSS (version 28.0); two-sided $\alpha = 0.05$.

Results

Table 2 presents the within-group pre–post changes for each outcome (n = 12 per group), reported as Δ (post−pre) with 95% CIs, paired t-test p-values, and Cohen's dz with qualitative magnitude. Consistent with the ANCOVA findings, singles-HIIT showed the largest improvements in anaerobic performance: peak power increased by 1.82 $W \cdot kg^{-1}$ (95% CI 1.54 to 2.10; $p < 0.001$; dz = 4.04, very large) and mean power by 1.96 $W \cdot kg^{-1}$ (95% CI 1.78 to 2.14; $p < 0.001$; dz = 7.69, very large). Doubles-HIIT and regHIIT also improved peak and mean power with large to very large effects (all $p < 0.001$), but to a lesser extent than singles-HIIT. All three HIIT formats increased VO_2max by ~2.3 $mL \cdot kg^{-1} \cdot min^{-1}$ (all $p < 0.001$; large to very large effects) and VIFT by ~0.96 - 1.00 $km \cdot h^{-1}$ (all $p < 0.001$; large to very large). The control group showed trivial changes in peak power and VIFT ($p = 0.356$ and $p = 0.783$, respectively), a moderate increase in mean power (Δ = 0.42 W·kg⁻¹; 95% CI 0.10 to 0.74; p=0.015; dz = 0.75), and a small-to-moderate rise in VO_2max (Δ = 0.32 mL·kg⁻¹·min⁻¹; 95% CI 0.03 to 0.61; p = 0.033; dz = 0.64). These within-group changes are descriptive and complement the between-group inferences derived from the ANCOVA models reported below.

Wingate peak power (primary outcome)

There was a significant Group effect on post-intervention Wingate peak power after adjustment for baseline ($F(3,43) = 89.10$, $p < 0.001$, partial $\eta^2 = 0.850$). Adjusted marginal means (±SE) were 10.005 ± 0.078 W·kg⁻¹ for singles-HIIT, 9.207 ± 0.077 W·kg⁻¹ for regHIIT, 9.152 ± 0.078 W·kg⁻¹ for doubles-HIIT, and 8.211 ± 0.077 W·kg⁻¹ for control.

Table 2. Pre- and post-intervention values for all measured variables, along with inferential statistics.

Group	n	Outcome	Pre-test (mean ± SD)	Post-test (mean ± SD)	Δ (post−pre)	95% CI for Δ	p-value	d (magnitude)	SMD (Hedges' g, post SD)
singlesHIIT	12	Peak Power (W·kg⁻¹)	8.43 ± 0.51	10.25 ± 0.52	1.82	1.52 to 2.11	p < 0.001	3.90 very large	1.74 (large)
singlesHIIT	12	Mean Power (W·kg⁻¹)	6.12 ± 0.51	8.08 ± 0.57	1.96	1.79 to 2.13	p < 0.001	7.45 very large	1.71 (large)
singlesHIIT	12	Fatigue index (%)	61.81 ± 6.91	49.20 ± 7.84	-12.60	-18.11 to -7.10	p < 0.001	-1.45 Large	−0.86 (moderate)
singlesHIIT	12	VO_2max (mL·kg⁻¹·min⁻¹)	50.14 ± 2.58	52.46 ± 1.90	2.32	1.61 to 3.03	p < 0.001	2.07 very large	1.00 (large)
singlesHIIT	12	VIFT (km·h⁻¹)	16.88 ± 0.43	17.79 ± 0.66	0.92	0.62 to 1.21	p < 0.001	1.96 Large	0.92 (large)
doublesHIIT	12	Peak Power (W·kg⁻¹)	7.93 ± 0.73	8.92 ± 0.77	1.00	0.86 to 1.13	p < 0.001	4.62 very large	1.29 (large)
doublesHIIT	12	Mean Power (W·kg⁻¹)	5.64 ± 0.65	6.60 ± 0.58	0.96	0.80 to 1.13	p < 0.001	3.70 very large	1.40 (large)
doublesHIIT	12	Fatigue index (%)	62.78 ± 6.65	57.08 ± 7.73	-5.70	-11.34 to -0.07	p = 0.048	-0.64 moderate	−0.46 (moderate)
doublesHIIT	12	VO_2max (mL·kg⁻¹·min⁻¹)	50.01 ± 2.20	52.37 ± 1.13	2.36	1.52 to 3.20	p < 0.001	1.78 large	0.98 (large)
doublesHIIT	12	VIFT (km·h⁻¹)	16.54 ± 0.45	17.54 ± 0.62	1.00	0.73 to 1.27	p < 0.001	2.35 very large	0.96 (large)
regHIIT	12	Peak Power (W·kg⁻¹)	8.21 ± 0.66	9.24 ± 0.68	1.03	0.91 to 1.16	p < 0.001	5.29 very large	1.52 (large)
regHIIT	12	Mean Power (W·kg⁻¹)	5.90 ± 0.57	6.89 ± 0.56	0.99	0.85 to 1.12	p < 0.001	4.64 very large	1.48 (large)
regHIIT	12	Fatigue index (%)	61.65 ± 7.66	55.37 ± 5.99	-6.28	-10.20 to -2.35	p = 0.005	-1.02 moderate	−0.58 (moderate)
regHIIT	12	VO_2max (mL·kg⁻¹·min⁻¹)	50.17 ± 1.74	52.50 ± 1.12	2.32	1.53 to 3.12	p < 0.001	1.86 large	0.91 (large)
regHIIT	12	VIFT (km·h⁻¹)	16.67 ± 0.49	17.62 ± 0.68	0.96	0.64 to 1.27	p < 0.001	1.92 large	0.87 (large)
control	12	Peak Power (W·kg⁻¹)	8.12 ± 0.67	8.16 ± 0.68	0.04	-0.07 to 0.15	p = 0.412	0.25 small	0.06 (trivial)
control	12	Mean Power (W·kg⁻¹)	5.73 ± 0.57	6.15 ± 0.66	0.42	0.07 to 0.77	p = 0.024	0.75 moderate	0.40 (moderate)
control	12	Fatigue index (%)	63.35 ± 4.38	53.76 ± 13.59	-9.59	-17.47 to -1.71	p = 0.021	-0.77 moderate	−0.39 (moderate)
control	12	VO_2max (mL·kg⁻¹·min⁻¹)	49.86 ± 1.86	50.18 ± 1.56	0.32	0.00 to 0.63	p = 0.048	0.64 moderate	0.17 (small)
control	12	VIFT (km·h⁻¹)	16.75 ± 0.58	16.71 ± 0.58	-0.04	-0.39 to 0.30	p = 0.795	-0.08 trivial	−0.02 (trivial)

regHIIT: running-based HIIT; HIIT: high-intensity interval training; VO_{2max}: maximal oxygen uptake. VIFT: velocity at 30-15 intermittent fitness test. Notes. Values are mean±SD. Δ is post−pre. p-values are from paired t-tests. Within-group effect size is Cohen's dz computed from the pre–post difference scores; qualitative thresholds: trivial <0.20, small 0.20 - 0.59, moderate 0.60 - 1.19, large 1.20 - 1.99, very large ≥2.00.

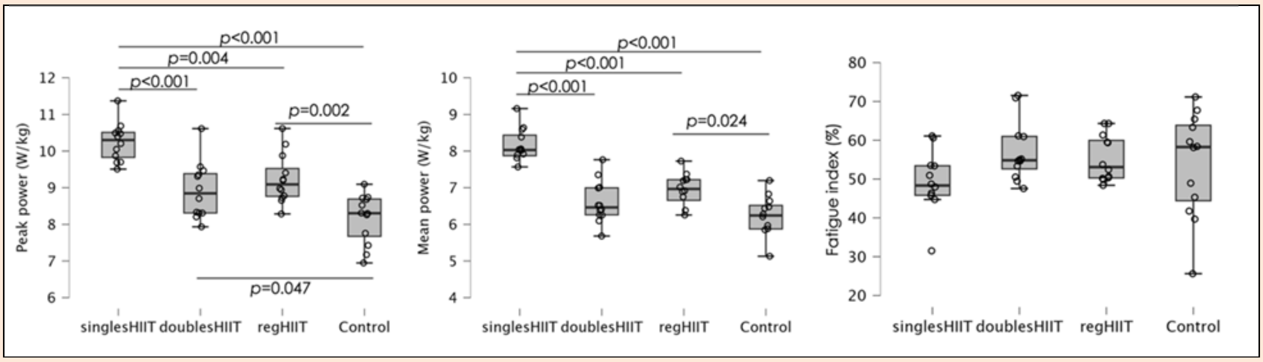

Figure 3. Boxplots of post-test anaerobic Wingate measures comparing the four groups.

The adjusted difference between singles-HIIT and doubles-HIIT was 0.853 $W \cdot kg^{-1}$ (95% CI 0.625 to 1.080; $p < 0.001$; $d = 3.09$), and between singles-HIIT and regHIIT was 0.798 $W \cdot kg^{-1}$ (95% CI 0.578 to 1.018; $p < 0.001$; $d = 2.89$). Doubles-HIIT and regHIIT did not differ ($\Delta = 0.055$ $W \cdot kg^{-1}$; 95% CI -0.165 to 0.274; $p = 0.620$). Each HIIT arm exceeded control: singles-HIIT versus control $\Delta = 1.794$ $W \cdot kg^{-1}$ (95% CI 1.572 to 2.015; $p < 0.001$; $d = 6.50$), doubles-HIIT versus control $\Delta = 0.941$ $W \cdot kg^{-1}$ (95% CI 0.717 to 1.166; $p < 0.001$; $d = 3.41$), and regHIIT versus control $\Delta = 0.996$ $W \cdot kg^{-1}$ (95% CI 0.770 to 1.222; $p < 0.001$; $d = 3.61$). Figure 3 shows the comparisons between groups for Wingate.

Wingate mean power

There was a significant Group effect ($F(3,43) = 49.65$, $p < 0.001$, partial $\eta^2 = 0.760$). Adjusted means (±SE) were 7.849 ± 0.094 $W \cdot kg^{-1}$ for singles-HIIT, 6.845 ± 0.091 $W \cdot kg^{-1}$ for regHIIT, 6.777 ± 0.093 $W \cdot kg^{-1}$ for doubles-HIIT, and 6.249 ± 0.092 $W \cdot kg^{-1}$ for control. Singles-HIIT exceeded doubles-HIIT by 1.072 $W \cdot kg^{-1}$ (95% CI 0.800 to 1.344; $p < 0.001$; $d = 3.07$) and exceeded regHIIT by 1.004 $W \cdot kg^{-1}$ (95% CI 0.742 to 1.266; $p < 0.001$; $d = 2.89$); singles-HIIT also exceeded control by 1.600 $W \cdot kg^{-1}$ (95% CI 1.332 to 1.867; $p < 0.001$). The regHIIT and doubles-HIIT each exceeded control (regHIIT vs control $\Delta = 0.596$ $W \cdot kg^{-1}$, 95% CI 0.330 to 0.862; $p < 0.001$; doubles-HIIT vs control $\Delta = 0.528$ $W \cdot kg^{-1}$, 95% CI 0.260 to 0.797; $p < 0.001$).

Fatigue index (%)

An ANCOVA comparing post-intervention FI% among groups, using baseline FI% as a covariate, revealed a non-significant group effect ($F(3,43) = 1.67$, $p = 0.189$, partial $\eta^2 = 0.104$), although baseline FI% significantly influenced post values ($F(1,43) = 5.78$, $p = 0.021$, partial $\eta^2 = 0.118$). Adjusted means (±SE) at the covariate mean (FI% pre = 62.40%) were 49.49 ± 2.54% for singles-HIIT, 55.74 ± 2.54% for reg-HIIT, 56.89 ± 2.54% for doubles-HIIT, and 53.29 ± 2.54% for control. No between-group differences reached significance after Bonferroni adjustment: singles-HIIT vs doubles-HIIT ($\Delta = -7.40\%$, 95% CI -17.33 to 2.53; $p = 0.272$; $d = 0.84$), singles-HIIT vs reg-HIIT ($\Delta = -6.24\%$, 95% CI -16.16 to 3.67; $p = 0.532$; $d = 0.71$), and singles-HIIT vs control ($\Delta = -3.80\%$, 95% CI -13.75 to 6.15; $p = 1.000$; $d = 0.43$). Pairwise differences among the HIIT groups and control were also non-significant (all $p \geq 0.189$).

VO_2max (mL·kg^{-1}·min^{-1})

There was a significant Group effect ($F(3,43) = 30.92$, $p < 0.001$, partial $\eta^2 = 0.664$). Adjusted means (±SE) were 52.402 ± 0.190 mL·kg^{-1}·min^{-1} for singles-HIIT, 52.420 ± 0.190 mL·kg^{-1}·min^{-1} for regHIIT, 52.389 ± 0.190 mL·kg^{-1}·min^{-1} for doubles-HIIT, and 50.291 ± 0.190 mL·kg^{-1}·min^{-1} for control. Each HIIT arm exceeded control: doubles-HIIT versus control $\Delta = 2.098$ mL·kg^{-1}·min^{-1} (95% CI 1.558 to 2.638; $p < 0.001$), regHIIT versus control $\Delta = 2.129$ mL·kg^{-1}·min^{-1} (95% CI 1.589 to 2.670; $p < 0.001$), and singles-HIIT versus control $\Delta = 2.111$ mL·kg^{-1}·min^{-1} (95% CI 1.571 to 2.652; $p < 0.001$). No differences were detected among the HIIT formats (all $p \geq 0.91$). Figure 4 shows the comparisons between groups for VO_{2max} and VIFT.

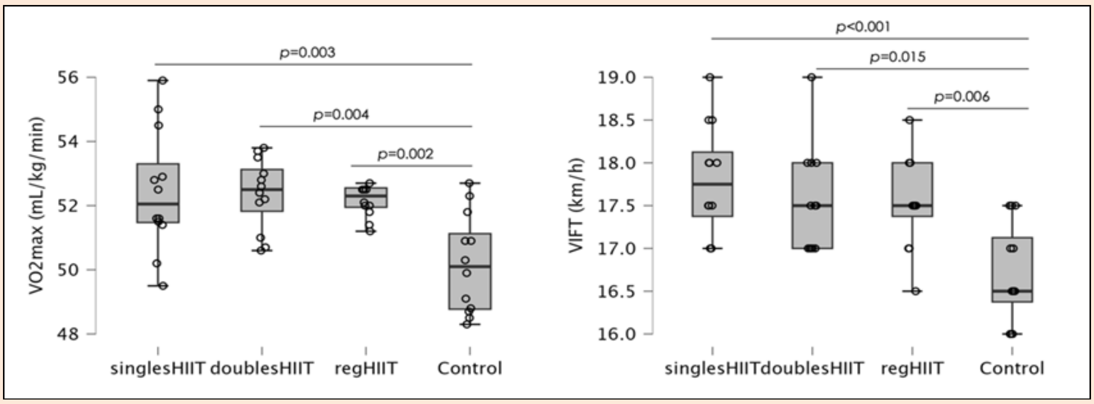

Figure 4. Boxplots of post-test maximal oxygen uptake (VO_{2max}) and final velocity at 30-15 Intermittent Fitness test (V_{IFT}) comparing the four groups.

VIFT (km·h⁻¹)

There was a significant Group effect ($F(3,43) = 14.80$, $p < 0.001$, partial $\eta^2 = 0.486$). Adjusted means (±SE) were 17.682 ± 0.131 km·h⁻¹ for doubles-HIIT, 17.660 ± 0.129 km·h⁻¹ for regHIIT, 17.651 ± 0.131 km·h⁻¹ for singles-HIIT, and 16.673 ± 0.129 km·h⁻¹ for control. Each HIIT arm exceeded control: doubles-HIIT versus control Δ = 1.009 km·h⁻¹ (95% CI 0.638 to 1.380; $p < 0.001$), regHIIT versus control Δ = 0.987 km·h⁻¹ (95% CI 0.620 to 1.354; $p < 0.001$), and singles-HIIT versus control Δ = 0.978 km·h⁻¹ (95% CI 0.610 to 1.346; $p < 0.001$). No differences were detected among the HIIT formats (all $p \geq 0.90$).

Discussion

The current research showed that while all HIIT interventions significantly improved anaerobic and aerobic performance compared to the control, singles HIIT was significantly more effective than doubles and regular HIIT in enhancing anaerobic peak and mean power. In contrast, all three HIIT interventions had a similar positive impact on aerobic performance measures such as VO_{2max} and VIFT.

Court-based interval training has demonstrated significant enhancements in peak and average power during the Wingate test (Zhao et al., 2024). Additionally, court-based repeated sprint training has shown advantages in improving repeated sprint ability compared to regular HIIT (Fernandez-Fernandez et al., 2012; Morais et al., 2024a). Our results for peak and mean power obtained in the Wingate test align with previous studies, suggesting that on-court drills, whether singles or doubles, can effectively enhance anaerobic performance. However, singles HIIT appears to be particularly more effective.

Singles HIIT likely imposes a greater anaerobic stimulus than doubles- or regHIIT because it integrates several compounding physical and physiological stressors. First, singles play produces a higher total movement volume and more frequent change-of-direction (COD) actions, as one player must cover the entire singles court. Meta-analytic and time–motion analyses report that singles players perform 600 - 800 m per set and often exceed 2 km of total movement per match, with hundreds of multidirectional accelerations and decelerations, compared with the shared workload in doubles (Pluim et al., 2023; Giles et al., 2024). Second, singles HIIT reproduces the sport's typical work-to-rest profile (~5 - 10 s work with ~10 - 20 s rest; 1:1 - 1:4 ratio), limiting phosphocreatine resynthesis between repetitions and increasing anaerobic contribution (Kovacs, 2006; Fernandez et al., 2006). Third, extended rallies and frequent COD efforts elicit higher blood lactate concentrations and heart-rate responses, particularly when points involve multiple strokes and prolonged movement phases (Mendez-Villanueva et al., 2007b; Murias et al., 2007). Fourth, singles play demands unilateral and rotational workload patterns that recruit asymmetrical trunk and limb musculature—patterns linked to specific hypertrophy and strength asymmetries in tennis athletes (Sanchis-Moysi et al., 2010; 2011; 2012). Finally, compared with regHIIT, on-court tennis intervals of equivalent mean oxygen consumption impose greater metabolic strain due to repeated accelerations, decelerations, and COD, which markedly elevate oxygen deficit and glycolytic contribution (Christmass et al., 1998; Ferrauti et al., 2001).

The intermittent, high-intensity nature of singles play, characterized by repeated rallies, rapid directional changes, and powerful groundstrokes, possibly stresses the phosphocreatine and glycolytic energy systems (Mendez-Villanueva et al., 2007a). This specificity of movement, coupled with the unpredictable work-to-rest ratios, potentially justifies the enhancements in peak and mean power by eventually promoting adaptations in enzyme activity, and intramuscular buffering capacity (Durmuş et al., 2023). Furthermore, the multi-planar demands of singles tennis (Pluim et al., 2023), involving lateral, rotational, and linear movements, likely necessitates a broader range of muscle activation compared to linear running, likely fostering greater neuromuscular adaptations and contributing to the enhanced power output measured in the Wingate test.

Both HIIT and OTT have been shown to improve aerobic capacity, as measured by VO_{2max} (Fernandez-Fernandez et al., 2012; Kilit and Arslan, 2019). Moreover, a previous study combining both OTT and HIIT also showed positive adaptations in aerobic capacity following the intervention (Morais et al., 2024a). Our results align with these previous studies (Fernandez-Fernandez et al., 2012; Kilit and Arslan, 2019), showing that regardless of the HIIT strategy—whether in the form of singles, doubles, or running—all three were equally effective in enhancing both VO_{2max} and VIFT, which are important markers of locomotor performance in response to HIIT training.

Beyond cardiorespiratory adaptations, on-court HIIT differs meaningfully from regHIIT by engaging the full tennis kinetic chain—lower limbs, trunk/hip rotation, and upper limb stroke actions—and by coupling conditioning with technical execution. Tennis movement inherently combines repeated accelerations, decelerations, and changes of direction (COD) with short work–rest cycles, producing distinct metabolic and mechanical demands compared with linear running of similar mean intensity (Christmass et al., 1998; Kovacs, 2006; Fernandez et al., 2006). On-court formats also integrate stroke production, so the upper extremities and trunk contribute substantially; long-term tennis practice is associated with sport-specific hypertrophy/asymmetry of trunk and dominant-arm musculature, consistent with the rotational/upper-limb loads that running does not provide (Sanchis-Moysi et al., 2010; 2011). Importantly, performing work while hitting balls adds a neuromuscular and coordinative layer (split-step, footwork into/out of strokes, stroke-timing under fatigue) that can degrade precision as fatigue accumulates—demands that are not present in regHIIT (Mendez-Villanueva et al., 2007b). Possibly, on-court HIIT provides sport-specific neuromuscular stimuli (COD braking/propulsion, trunk-rotation coupling, upper-limb power and control during strokes) that likely enhance transfer to competitive performance beyond what is achievable with lower-limb-dominant, linear regHIIT.

Possibly, the intermittent stress leads to improvements in cardiovascular function, including increased stroke volume and cardiac output, facilitating greater oxygen delivery to working muscles (Pialoux et al., 2015). Furthermore, these training protocols likely stimulate mitochondrial biogenesis, enhancing the muscles' capacity for oxidative phosphorylation and thus improving VO_{2max} (Liu et al., 2024). Repeated high-intensity efforts eventually drive adaptations in muscle buffering capacity, allowing for better tolerance of lactate accumulation and contributing to improved performance in the intermittent fitness test, reflected in the increased final velocity (Edge et al., 2006). The specific adaptations induced by tennis-specific drills (singles and doubles without serving) mirror the intermittent nature of the sport, further enhancing the transfer of training effects to on-court performance.

Beyond the physiological mechanisms, recent research emphasizes that HIIT in tennis also induces meaningful cognitive and perceptual adaptations. For example, a study (Clemente-Suárez et al., 2022) reported that HIIT performed under cognitive load (via Stroop tasks) increased perceived exertion and reduced serve accuracy, revealing how cognitive stressors interact with motor performance. Similarly, another study (Díaz-García et al., 2023) found that adding cognitive tasks during HIIT elevated mental fatigue without altering physical workload, suggesting a decoupling between mental and physical strain that can be beneficial for developing attentional control during fatigue. From a performance perspective, two studies (Morais et al., 2024a; Fan et al., 2025) showed that both on-court HIIT and sprint interval formats improve aerobic capacity and repeated-sprint ability, with on-court designs enhancing ecological validity and technical consistency. Complementary evidence from two other studies (Suárez Rodríguez and del Valle Soto, 2017; Oliveira et al., 2025) highlights that specific, intermittent drills improve agility, movement precision, and overall performance efficiency in young tennis players. Furthermore, a study (Villafaina et al., 2020) demonstrated that tennis-based HIIT can enhance agility and strength even in clinical populations, reinforcing its broad applicability. These findings suggest that HIIT protocols not only drive aerobic and anaerobic adaptations but also foster cognitive resilience, motor precision, and perceptual efficiency—components that are critical to tennis performance under competitive conditions.

Some factors constrain the generalizability of these findings. One factor is that only male players were included; sex-related differences in acute HIIT responses and recovery kinetics have been documented (Schmitz et al., 2020; Hottenrott et al., 2021). Moreover, participants were trained but non-elite; adaptation magnitude and transfer can vary with training status, as outlined in HIIT programming reviews (Buchheit and Laursen, 2013) and competitive level influences match demands (Kovalchik and Reid, 2017). Additionally, our sample comprised young adults; HIIT responses differ across age groups, with distinct considerations in youth (Engel et al., 2018). Finally, all sessions were conducted on hard courts; internal load, movement mechanics, and technical responses vary by court surface (Reid et al., 2013). Another factor affecting ecological validity is the no-serve design of the HIIT drills. Serving is a key element of tennis performance, contributing to both technical and neuromuscular demands. Thus, excluding serve actions may limit the direct transferability of findings to actual match play conditions.

Although singles HIIT showed a superior effect on anaerobic peak and mean power, the mechanisms behind these improvements—such as specific neuromuscular adaptations and changes in enzyme activity—remain to be fully understood. Future studies could focus on investigating these underlying physiological processes to better understand why singles HIIT is more effective in enhancing anaerobic performance. Additionally, while all HIIT interventions equally improved aerobic performance measures, further research could explore whether combining different HIIT formats, such as singles and doubles, could lead to greater overall improvements in both aerobic and anaerobic fitness. Moreover, examining the impact of training protocols on sport-specific performance, including the inclusion of tennis serving, could provide more direct insights into how these HIIT strategies translate to on-court performance.

Although all HIIT formats were matched for total duration and work-to-rest structure, the singles-based drills elicited slightly higher RPE values than doubles or running HIIT, suggesting greater individual physiological stress. Therefore, the superior anaerobic adaptations observed in the singles-HIIT group should be interpreted considering this potentially higher internal load. Finally, although participants were already familiar with the tests as part of their regular routines, residual learning effects cannot be fully excluded.

Despite the limitations, the findings of this study offer some practical applications for tennis coaches and athletes looking to enhance both anaerobic and aerobic performance through HIIT. Specifically, singles HIIT appears to be the most effective protocol for improving anaerobic power, making it a valuable tool for athletes seeking to boost power during intense, short-duration rallies. Coaches can incorporate singles HIIT drills into their training sessions, emphasizing rapid directional changes and powerful groundstrokes to mimic the high-intensity, intermittent demands of singles play. For improving aerobic capacity, all forms of HIIT—whether singles, doubles, or regHIIT—proved equally effective, suggesting that coaches can select the most convenient or sport-specific format based on their training environment and athlete preferences.

Conclusion

In conclusion, this study demonstrates that high-intensity interval training (HIIT) is effective in improving both anaerobic and aerobic performance in competitive tennis players. All HIIT interventions—singles, doubles, and running-based (regHIIT)—produced significant gains in aerobic capacity, confirming the versatility of these training formats for enhancing overall fitness. Under the present conditions, singles-HIIT appeared particularly effective in improving anaerobic peak and mean power, suggesting that this format may be preferable when the goal is to enhance anaerobic performance.

These results should, however, be interpreted with some caution, as intensity during the on-court formats was monitored through perceived exertion rather than direct physiological measures, and singles-HIIT elicited slightly higher RPE values than the other formats. Therefore, part of the observed superiority of singles-HIIT may reflect a higher internal load rather than the playing format itself.

Aerobic benefits were comparable across all HIIT modalities, indicating that diverse HIIT approaches can similarly promote cardiovascular adaptations. By integrating sport-specific HIIT strategies, coaches can enhance both aerobic endurance and explosive power—key performance components for success in modern tennis—while selecting the most appropriate format according to the desired physiological emphasis.

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The author reports no actual or potential conflicts of interest. While the datasets generated and analyzed in this study are not publicly available, they can be obtained from the corresponding author upon reasonable request. All experimental procedures were conducted in compliance with the relevant legal and ethical standards of the country where the study was carried out. The authors declare that no Generative AI or AI-assisted technologies were used in the writing of this manuscript.

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Key points

- Singles HIIT significantly improved peak and mean anaerobic power compared to doubles HIIT and traditional running HIIT.
- Singles HIIT showed superior benefits in both anaerobic and aerobic performance, suggesting its value in optimizing tennis-specific conditioning.
- Both singles and doubles HIIT, as well as regular HIIT, led to significant increases in VO2max and VIFT scores compared to the control group.

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