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The transformative impact of high-intensity interval training on performance indicators among adolescent tennis players

El impacto transformador del entrenamiento interválico de alta intensidad en los indicadores de rendimiento de jugadores adolescentes de tenis

Authors

Prashant Kumar Choudhary [1]
Suchishrava Choudhary [1]
Sohom Saha [1]
Debajit Karmakar [1]
Yajuvendra Singh Rajpoot [1]
Arnav Sharma [1]
Sambhu Prasad [2]
Bhanu Pratap [3]
Dharmendra Singh [4]
Khushbu Sisodiya [1]
Pradeep Prajapati [1]

[1] Lakshmibai National Institute of Physical Education, Madhya Pradesh (India)
[2] Rajib Gandhi University, Arunachal Pradesh (India)
[3] Amity School of Physical Education and Sports Sciences (India)
[4] Jawaharlal Nehru Krishi Vishwa Vidyalaya, Madhya Pradesh (India)

Corresponding author:
Debajit Karmakar
debajitkarmakar2200@gmail.com

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Abstract

Introduction: High-Intensity Interval Training (HIIT) is an established method for improving athletic performance; however, its efficacy in adolescent tennis players remains underexplored. Tennis requires a combination of speed, agility, endurance, and explosive power, making sport-specific HIIT a promising intervention for performance enhancement.
Objective: This study aimed to investigate the effects of an 8-week HIIT intervention on key physiological and performance parameters in adolescent tennis players.
Methodology: Thirty-six intermediate-level male tennis players (aged 15-19 years) were randomly assigned to an experimental group (n=18), which underwent 20 HIIT sessions, or a control group (n=18), which followed conventional training. Performance assessments included maximal oxygen uptake ($\dot{V}O_2max$), explosive power (countermovement jump, squat jump, drop jump), sprint performance (5m, 10m), and agility (modified t-test). Statistical analyses were conducted using repeated-measures ANOVA.
Results: The experimental group demonstrated significant improvements ($p < .001$) across all parameters: $\dot{V}O_2max$ increased by 4.84%, CMJ by 15.44%, SJ by 10.77%, DJ by 12.40%, while sprint times decreased by 2.73% (5m) and 6.51% (10m). Agility improved by 8.08%. The control group exhibited negligible changes.
Discussion: The observed enhancements highlight HIIT's efficacy in optimizing aerobic and anaerobic capacities, neuromuscular efficiency, and explosive power, aligning with the physiological demands of tennis.
Conclusion: HIIT presents a time-efficient, sport-specific training method for improving tennis performance, warranting further exploration for long-term athletic development.

Keywords

Cardiorespiratory fitness; explosive power; sprint Performance; young athletes.

Resumen

Introducción: El Entrenamiento Interválico de Alta Intensidad (HIIT) es un método reconocido para mejorar el rendimiento deportivo; sin embargo, su eficacia en jugadores adolescentes de tenis sigue siendo poco estudiada. El tenis requiere una combinación de velocidad, agilidad, resistencia y potencia explosiva, lo que hace que el HIIT específico para este deporte sea una intervención prometedora para la mejora del rendimiento.
Objetivo: Este estudio tuvo como objetivo analizar los efectos de una intervención de HIIT de 8 semanas en parámetros fisiológicos y de rendimiento en jugadores adolescentes de tenis.
Metodología: Treinta y seis tenistas masculinos de nivel intermedio (15-19 años) fueron asignados aleatoriamente a un grupo experimental (n=18), que realizó 20 sesiones de HIIT, o a un grupo de control (n=18), que siguió un entrenamiento convencional. Se evaluaron el consumo máximo de oxígeno ($\dot{V}O_2max$), la potencia explosiva (salto con contramovimiento, salto en cuclillas, salto desde caída), la velocidad en esprints (5m, 10m) y la agilidad (prueba T modificada). Se aplicó ANOVA de medidas repetidas para el análisis estadístico.
Resultados: El grupo experimental mostró mejoras significativas ($p < .001$) en todos los parámetros: $\dot{V}O_2max$ aumentó un 4.84%, CMJ un 15.44%, SJ un 10.77%, DJ un 12.40%, mientras que los tiempos de esprint disminuyeron en un 2.73% (5m) y 6.51% (10m). La agilidad mejoró un 8.08%. El grupo de control mostró cambios mínimos.
Discusión y conclusión: Los resultados destacan la eficacia del HIIT en la optimización de la capacidad aeróbica, anaeróbica y neuromuscular, alineándose con las demandas fisiológicas del tenis. Se recomienda explorar más su aplicación en el desarrollo atlético a largo plazo.

Palabras clave

Aptitud cardiorrespiratoria; potencia explosiva; rendimiento en esprints; jóvenes atletas.

Introduction

High-Intensity Interval Training (HIIT) has emerged as a pivotal training methodology in sports performance optimization, particularly in tennis, a sport characterized by intermittent, explosive movements and high-energy demands. This training approach involves alternating short periods of intense anaerobic exercise with less-intense recovery periods, strategically designed to enhance physiological adaptations and performance capabilities (Fernandez-Fernandez et al., 2008; Mendez-Villanueva et al., 2007).

Traditional continuous training approaches often fail to comprehensively address the sport's unique metabolic and neuromuscular requirements. HIIT emerges as a scientifically substantiated training intervention that precisely mimics the intermittent nature of tennis match dynamics (Sperlich et al., 2017). Tennis is a complex sport requiring multifaceted athletic capabilities, including speed, power, agility, and sustained performance under competitive stress. Traditional continuous training models have increasingly been challenged by HIIT's ability to more effectively improve athletes' physiological parameters. High-Intensity Interval Training (HIIT) for tennis players is a specialized form of cardiovascular conditioning that alternates between short bursts of intense activity and brief periods of active recovery. By incorporating sport-specific drills such as sprint intervals, lateral shuffles, and explosive footwork, HIIT not only improves physical fitness but also sharpens on-court responsiveness and resilience under fatigue. The physiological mechanisms underlying HIIT's effectiveness are multifaceted.

Research indicates that this training approach significantly enhances mitochondrial biogenesis, improves oxidative enzyme activity, and increases muscle buffer capacity more efficiently than traditional moderate-intensity continuous training (Hawley et al., 2014). Moreover, HIIT induces superior cardiovascular adaptations, including improved VO2 max, enhanced cardiac output, and accelerated lactate threshold, which are critical determinants of athletic performance in high-intensity sports like tennis (Laursen, 2010). For young tennis players, this training method offers a time-efficient approach to developing critical performance metrics while minimizing potential overtraining risks. Existing literature provides substantial evidence supporting HIIT's effectiveness across various sports. Studies by Laursen and Jenkins (2013) highlighted HIIT's potential in enhancing both aerobic and anaerobic energy systems (Buchheit & Laursen, 2013). Studies by Rønnestad et al. (2020) highlighted HIIT's potential in enhancing endurance performance, yet comprehensive investigations specific to tennis-related multidirectional movement patterns are scarce (Rønnestad et al., 2020). However, tennis-specific research remains relatively fragmented. While some investigations have explored HIIT's impact on general athletic performance, comprehensive studies focusing specifically on young tennis players' physiological responses are limited (Rønnestad & Mujika, 2014; Strøyer et al., 2004). Recent epidemiological data underscore the increasing competitiveness in junior tennis and the critical role of advanced training methodologies.

The International Tennis Federation (ITF) reports a 22% increase in youth tournament participation globally between 2015-2022, highlighting the growing demand for scientifically validated training interventions (Koral et al., 2018). Moreover, emerging research suggests that targeted high-intensity training can potentially reduce injury risks while simultaneously enhancing performance capabilities (Bishop & Girard, 2013; Ulbricht et al., 2016). Statistical trends further emphasize the necessity of innovative training approaches: Approximately 68% of elite junior tennis players incorporate some form of interval-based training in their regimens (Mohr et al., 2003). Performance improvements of 12-18% have been observed in athletes implementing sport-specific HIIT protocols (Bartlett et al., 2011). Reduced training volume with HIIT has shown equivalent or superior physiological adaptations compared to traditional training methods (Girard et al., 2006; Mujika & Padilla, 2003). High-Intensity Interval Training represents a promising frontier in sports performance enhancement. By systematically investigating its impacts on young tennis players, our research aspires to contribute meaningful insights that could reshape contemporary training paradigms, ultimately supporting athletes' developmental journeys.

Method

Participants of the Study

This study included thirty-six intermediate-level, right-handed male tennis players aged between 15 and 19 years, selected from the M.P. states of India. Participants were randomly assigned to an experimental group (n=18) and a control group (n=18). Before participation, the players and their parents were briefed on the study's objectives, procedures, and potential risks. Prior to the start of the study, participants and their guardians received detailed information about the research, both verbally and in written form. Consent was documented through signed informed consent forms, indicating each participant's voluntary agreement to participate. The players were familiar with a training workload of more than three training units per week. All study procedures were carried out strictly according to the ethical standards specified in the Declaration of Helsinki for Medical Research Involving Human Subjects (World Medical Association, 2013).

Figure 1. CONSORT Flow Chart

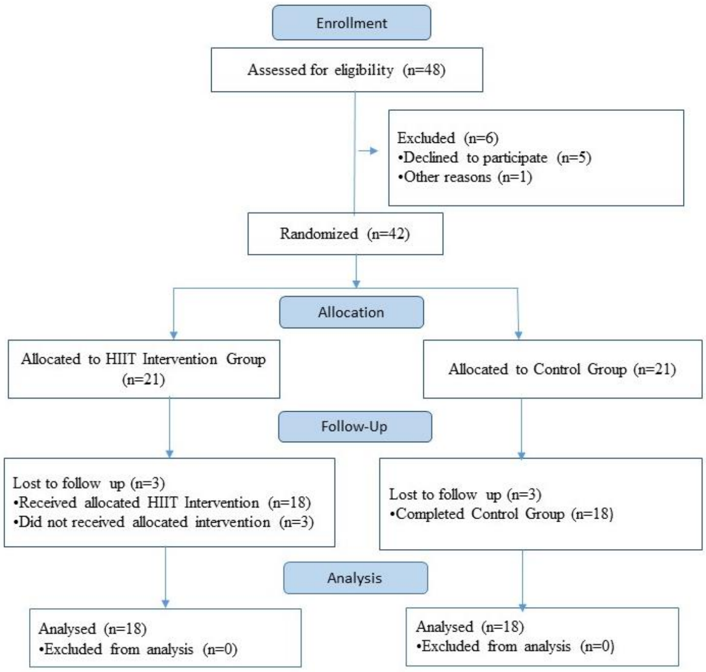


Table 1. Demographic Values for Participants

Measures	EG	CG
Age (Yrs)	16.66±1.45	16.38±1.50
Weight (kg)	50.72±3.21	50.83±3.11
Height (cm)	155±1.94	155.83±3.65

*EG; Experimental Group, CG; Control Group

Training Procedure

The training program comprised 20 sessions organized over 8 weeks, meticulously designed to prevent muscle and tendon injuries and minimize the accumulation of psychophysiological fatigue. During Weeks 1 and 8, participants engaged in 2 sessions, while Weeks 2, 3, 4, and 5 included 3 sessions each.

Table 2. Presents the HIIT training sessions for the Eight-week program

Week	Training Session	HIIT Training Prescription	Total Time (mins)
	1	6 × 30-s sprint / 30-s rest	8
1	2	8 × 30-s sprint / 30-s rest	10
	3	10 × 30-s sprint / 30-s rest, 1.5-min rest	13
2	4	6 × 30-s sprint / 30-s rest, 1.5-min rest	9
	5	8 × 30-s sprint / 30-s rest, 1-min rest	12

	6	10 × 30-s sprint / 30-s rest, 1.5-min rest	13
3	7	8 × 30-s sprint / 30-s rest, 1.5-min rest	12
	8	10 × 30-s sprint / 30-s rest, 1-min rest	14
	9	8 × 30-s sprint / 30-s rest, 1-min rest	12
4	10	10 × 30-s sprint / 30-s rest, 1.5-min rest	13
	11	12 × 30-s sprint / 30-s rest, 2-min rest	16
	12	8 × 30-s sprint / 30-s rest, 1.5-min rest	12
5	13	10 × 30-s sprint / 30-s rest, 1.5-min rest	13
	14	10 × 30-s sprint / 30-s rest, 1-min rest	14
	15	12 × 30-s sprint / 30-s rest, 2-min rest	16
6	16	12 × 30-s sprint / 30-s rest, 2-min rest	16
7	17	10 × 40-s sprint / 30-s rest, 1.5-min rest	15
	18	10 × 30-s sprint / 30-s rest, 1-min rest	14
8	19	12 × 40-s sprint / 30-s rest, 2-min rest	18
	20	12 × 30-s sprint / 30-s rest, 1.5-min rest	16
Cumulative total time, to track the overall duration of the training program across the weeks.			266

To ensure optimal recovery, a minimum of 48 hours separated each training session, which was especially important as the program took place in the preseason phase, free from match play. Each session began with a standardized 5-minute warm-up that included low-intensity running, dynamic stretching, and short submaximal sprints tailored to tennis-specific actions. This was followed by tennis drills focusing on fundamental techniques, such as forehand and backhand strokes from the baseline, serves and returns, volleys, and overhead shots, all conducted for 25 minutes. The warm-up and drill sequence was crafted to engage players without excessive fatigue, setting an effective foundation for the subsequent high-intensity interval training (HIIT) component. The HIIT segment was performed on a 400-meter athletics track without rackets, lasting between 8–16 minutes per session.

Players were encouraged to exert maximum effort during these intervals, achieving over 85% of their individual maximum heart rate (HRmax) across the high-intensity intervals, which were interspersed with passive recovery periods of 1–2 minutes. Exercise intensities during HIIT were classified across five heart rate zones for precise control: Zone 1 (<60% HRmax), Zone 2 (61–70% HRmax), Zone 3 (71–80% HRmax), Zone 4 (81–90% HRmax), and Zone 5 (>91% HRmax). This classification allowed for targeted progression in intensity as players acclimatized to the demands of the program. This structured, progressive training protocol facilitated performance gains while safeguarding against overtraining and injury. The control group of tennis players followed their regular training routine without any additional interventions or specialized conditioning programs. Their regimen was consisted of standard tennis practice sessions focusing on technical skills, match play, and general physical activity as prescribed by their coaches. This includes warm-up drills, rally practice, serving, and basic footwork exercises typically performed during regular training. The control group didn't participate in high-intensity interval training or any structured fitness program introduced in the experimental groups, ensuring a baseline for comparison in evaluating the effectiveness of the specific training interventions on targeted performance variables.

Testing protocol

All assessments were conducted over two consecutive days under standardized laboratory conditions (temperature: 23±1°C, relative humidity: 45±5%). Participants were instructed to avoid strenuous physical activity for 48 hours before testing and maintain their normal dietary habits, following protocols established by Laursen et al. (Laursen et al., 2007). All tests were performed at the same time of day (±2 hours) to minimize circadian rhythm effects on performance, as recommended by Drust et al. (Drust et al., 2005).

Day 1 Testing

Anthropometric Measurements

Height was measured using a stadiometer (Seca 213, Hamburg, Germany) to the nearest 0.1 cm, and body mass was recorded using a calibrated digital scale (Tanita BC-545N, Tokyo, Japan) to the nearest 0.1 kg, following the standardized procedures described by Stewart et al. (Stewart et al., 2011).

Maximal Oxygen Uptake ($\dot{V}O_2max$)

$\dot{V}O_2max$ was assessed using a progressive incremental test to exhaustion on a motorized treadmill (h/p/cosmos pulsar, Nussdorf-Traunstein, Germany), following the protocol validated by Fernandez-Fernandez et al. (Fernandez-Fernandez et al., 2014). After a standardized 5-minute warm-up at 8 km/h, the test began at 10 km/h with 1% gradient. Speed increased by 1 km/h every 2 minutes until volitional exhaustion, as per established procedures (Midgley et al., 2007). Respiratory gas exchange was measured continuously using a calibrated breath-by-breath gas analysis system (Cortex Metalyzer 3B, Leipzig, Germany). Heart rate was monitored using a telemetric device (Polar H10, Kempele, Finland). $\dot{V}O_2max$ was considered achieved when at least three of the following criteria were met (Howley et al., 1995):

- Respiratory exchange ratio (RER) > 1.10
- Heart rate within 10 beats/min of age-predicted maximum
- Plateau in $\dot{V}O_2$ despite increasing workload
- Rating of perceived exertion (RPE) ≥ 19 on the 6-20 Borg scale
- Blood lactate concentration > 8 mml/L

Day 2 Testing

Jump Performance

Following a standardized 10-minute dynamic warm-up protocol validated by Reid et al. (Reid & Schneiker, 2008), participants performed three types of vertical jumps with 3-minute rest intervals between attempts, as prescribed by Kovacs et al. (Kovacs et al., 2007):

1. Countermovement Jump (CMJ): Following the protocol established by Markovic et al. (Markovic et al., 2004), Participants began in an upright position with hands on hips, then executed a quick downward movement followed by an explosive vertical jump.
2. Squat Jump (SJ): Using procedures validated by Girard and Millet (Girard & Millet, 2009), participants started from a 90° knee flexion position with hands on hips and performed a maximal vertical jump without countermovement.

Drop Jump (DJ): Following methods described by Young et al. (Young et al., 1995), participants stepped off a 40-cm box, landed on both feet, and immediately performed a maximal vertical jump.

All jumps were performed on a force platform (Kistler 9290AD, Winterthur, Switzerland) sampling at 1000 Hz. Three attempts were allowed for each jump type, with the best performance used for analysis, consistent with established protocols (Gathercole et al., 2015).

Sprint Performance

Linear sprint ability was assessed over 5m and 10m distances using electronic timing gates (Microgate Witty, Bolzano, Italy), following procedures validated by Fernandez-Fernandez et al. (Fernandez-Fernandez et al., 2009). Participants started 0.5m behind the first timing gate in a two-point stance position. Three attempts were permitted with 3-minute recovery periods between trials, as recommended by Spencer et al. (Spencer et al., 2006).

Agility Performance

Agility was evaluated using the modified T-test protocol validated by Pauole et al. (Pauole et al., 2000). The test configuration and procedures followed standardized guidelines established for tennis-specific testing (Ferrauti et al., 2011). Electronic timing gates were positioned at the start/finish line. Three trials were performed with 3-minute recovery periods, adhering to rest intervals validated by Vescovi and McGuigan (Vescovi & McGuigan, 2008).

Statistical Analysis

Data analysis was conducted using SPSS software version 26 (SPSS, Inc., Chicago, IL, USA), with statistical significance set at $p \leq 0.05$. Data were presented as mean ± SD. To assess within-group changes from the pre-test to the post-test, a paired sample t-test was applied. Between-group differences were examined by using repeated-measures ANOVA. Effect sizes (η^2_p) were computed for each variable, with thresholds defined as follows- small: less than 0.06; moderate 0.06 to 0.13; and large 0.04 and more (Siby et al., 2024).

Results

¡Error! La autoreferencia al marcador no es válida. presents the comparative analysis of pre- and post-test results for physiological and performance metrics in young tennis players subjected to High-Intensity Interval Training (HIIT). Significant improvements were observed in the experimental group across all measured variables, while the control group showed negligible changes. For VO2 Max, the experimental group increased from 44.83 ± 0.85 to 47.00 ± 1.13, with a statistically significant effect (SS = 23.34, F = 111.19, p < .001, η^2p = 0.76), whereas the control group remained stable (44.80 ± 0.85 to 44.72 ± 1.01). In performance metrics, the Countermovement Jump (CMJ) improved substantially in the experimental group from 27.72 ± 1.17 to 32.00 ± 1.08 (SS = 82.34, F = 358.69, p < .001, η^2p = 0.91), with no change in the control group (27.94 ± 1.21 to 27.94 ± 1.25). Similarly, the Squat Jump (SJ) performance in the experimental group increased significantly from 29.44 ± 1.09 to 32.61 ± 1.09 (SS = 50.00, F = 109.67, p < .001, η^2p = 0.76), while the control group showed negligible variation (29.72 ± 1.52 to 29.55 ± 1.46). For Drop Jump (DJ), the experimental group improved from 29.11 ± 1.60 to 32.72 ± 1.32 (SS = 58.68, F = 196.78, p < .001, η^2p = 0.85), with no improvement in the control group (29.16 ± 1.75 to 29.16 ± 1.72). Speed performance also improved in the experimental group, as evidenced by a decrease in 5 m Sprint time from 1.10 ± 0.01 to 1.07 ± 0.01 (SS = 0.004, F = 204.94, p < .001, η^2p = 0.85) and in 10 m Sprint time from 2.15 ± 0.01 to 2.01 ± 0.01 (SS = 0.005, F = 117.76, p < .001, η^2p = 0.77), with minimal changes in the control group for both distances. Lastly, agility improved significantly in the experimental group, with times decreasing from 11.14 ± 0.22 to 10.24 ± 0.25 (SS = 3.17, F = 146.19, p < .001, η^2p = 0.81), while the control group showed only a minor change (11.12 ± 0.18 to 11.06 ± 0.31). These findings underscore the efficacy of HIIT in enhancing physiological and performance outcomes in young tennis players.

Table 3. Impact of High-Intensity Interval Training on Physiological and Performance Metrics in Young Tennis Players: Comparative Analysis of Pre and Post Test Results Across Experimental and Control Groups

Variables	Groups	Pre data (M±SD)	Post data (M±SD)	SS	F	p	η^2_p
VO2 Max	Experimental Group	44.83±0.85	47±1.13	23.34	111.19	< .001	0.76
	Control Group	44.80±0.85	44.72±1.01				
CMJ	Experimental Group	27.72±1.17	32±1.08	82.34	358.69	< .001	0.91
	Control Group	27.94±1.21	27.94±1.25				
SJ	Experimental Group	29.44±1.09	32.61±1.09	50.00	109.67	< .001	0.76
	Control Group	29.72±1.52	29.55±1.46				
DJ	Experimental Group	29.11±1.6	32.72±1.32	58.68	196.78	< .001	0.85
	Control Group	29.16±1.75	29.16±1.72				
5 m Sprint	Experimental Group	1.10±0.01	1.07±0.01	0.004	204.94	< .001	0.85
	Control Group	1.10±1.01	1.10±0.01				
10 m Sprint	Experimental Group	2.15±0.01	2.01±0.01	0.005	117.76	< .001	0.77
	Control Group	2.16±0.01	2.15±0.01				
Agility	Experimental Group	11.14±0.22	10.24±0.25	3.17	146.19	< .001	0.81
	Control Group	11.12±0.18	11.06±0.31				

$\dot{V}O_2$ max- Maximal oxygen uptake; CMJ - Countermovement jump; SJ- Squat jump; and DJ- Drop jump

Figure 2. Graphical Representation of Physiological Performance Indicators Before and After High-Intensity Interval Training Among Adolescent Tennis Players

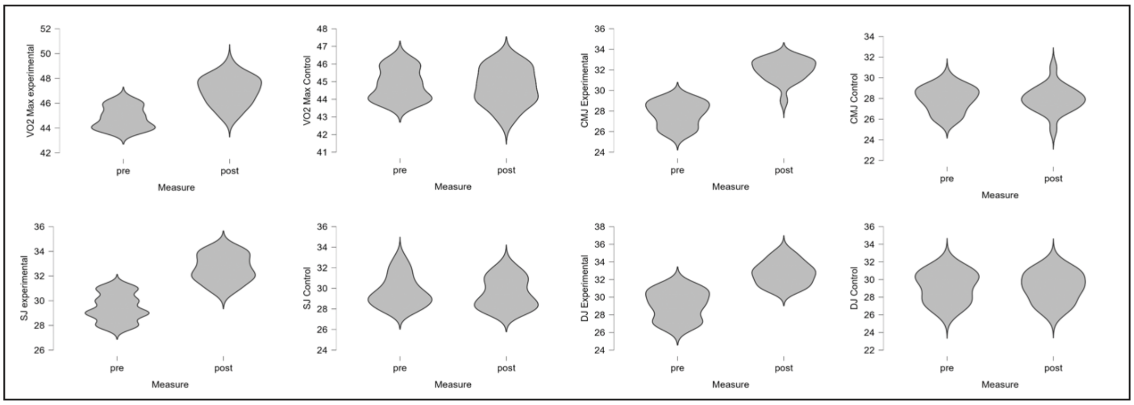
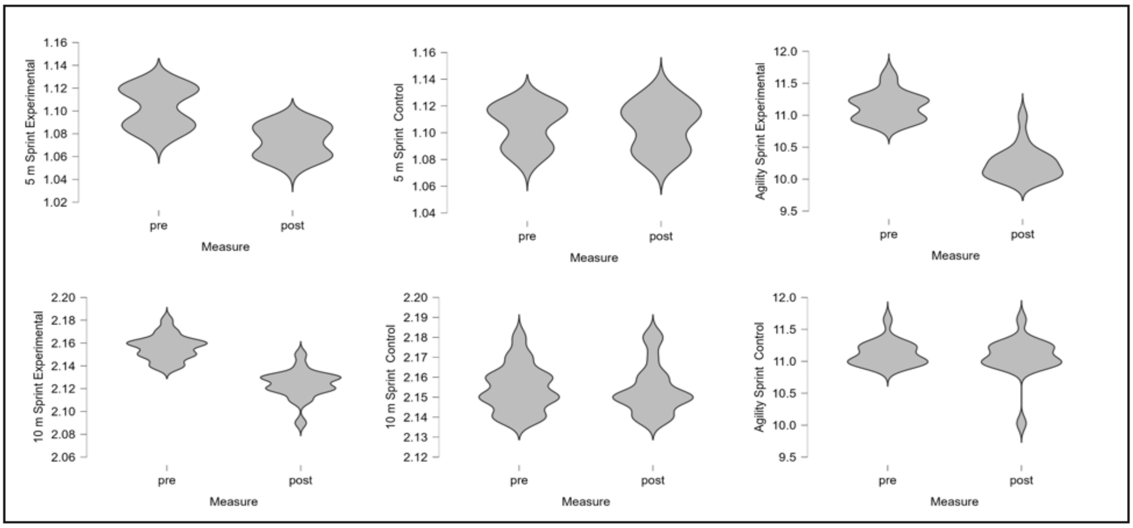


Figure 3. Graphical Representation of Speed and Agility Performance Indicators Before and After High-Intensity Interval Training Among Adolescent Tennis Players



Discussion

This enhancement in cardiorespiratory fitness is attributable to the physiological adaptations induced by the repeated exposure to short bursts of high-intensity effort interspersed with recovery periods (Marterer et al., 2020). High-intensity interval training elicits a substantial overload on the cardiovascular and respiratory systems, which stimulates adaptations such as increased stroke volume, enhanced capillary density, and improved mitochondrial efficiency (Groeber et al., 2020). These changes collectively enable more efficient oxygen uptake, transportation, and utilization during physical activity, thereby elevating the maximum oxygen consumption capacity. Additionally, the repeated surges in intensity promote the recruitment of a larger proportion of muscle fibers, particularly type II fibers, which are typically underutilized during steady-state exercise. This contributes to improved muscular oxygen extraction and overall aerobic capacity (Herrera-Valenzuela et al., 2021). The structured nature of high-intensity interval training also ensures that participants achieve and sustain near-maximal heart rates during exercise bouts, creating optimal conditions for physiological adaptations that enhance VO2 max (Hatle et al., 2014). Furthermore, the recovery intervals provide sufficient time for partial metabolic recovery, allowing participants to maintain higher intensities during subsequent efforts. This cyclical stress and recovery process not only maximizes cardiovascular and muscular workload but also facilitates greater improvements in aerobic capacity compared to traditional moderate-intensity continuous training (Cao et al., 2021). These findings underscore the efficacy of high-intensity interval training as a time-efficient and impactful strategy for improving VO2 max among individuals seeking to enhance their cardiorespiratory fitness and overall athletic performance.

The significant improvements observed in the countermovement jump, squat jump, and drop jump among participants following high-intensity interval training are indicative of enhanced neuromuscular and physiological adaptations (Wells et al., 2014). High-intensity interval training is characterized by short bursts of intense exercise interspersed with periods of rest or low-intensity activity, which provides a potent stimulus for both the muscular and nervous systems. The countermovement jump, which relies heavily on the stretch-shortening cycle, benefits from increased elastic energy utilization and improved motor unit recruitment (Seo et al., 2019). Enhanced synchronization and firing frequency of motor units likely contribute to the improved performance in the countermovement jump, as participants develop the ability to produce force more efficiently during the eccentric-concentric transition phase. Similarly, the squat jump, which isolates concentric muscle contraction by eliminating the stretch-shortening cycle, reflects the development of pure muscular strength and power (Wells et al., 2014). High-intensity interval training induces muscular hypertrophy, particularly in the lower limb muscles, and improves anaerobic energy production, enabling participants to generate greater force during the explosive phase of the squat jump. The emphasis on rapid, high-intensity efforts during training also enhances phosphocreatine system efficiency, ensuring that participants can sustain maximal power output during such movements (Wells et al., 2014). For drop jump, which evaluates reactive strength and plyometric ability, demonstrates marked improvement due to the enhancement of stretch reflex efficiency and tendon elasticity developed through high-intensity interval training (Seo et al., 2019). The repeated exposure to high-impact, explosive efforts during training conditions the musculoskeletal system to better tolerate and utilize eccentric loading forces, resulting in a more effective rebound phase during the drop jump (Cao et al., 2021). This improvement is further supported by neural adaptations, such as enhanced pre-activation of muscles and reduced electromechanical delay, which optimize the time taken to transition from the eccentric to concentric phase of the jump (Seo et al., 2019). The metabolic demands of high-intensity interval training stimulate increased anaerobic capacity and lactate threshold, enabling participants to perform explosive movements with reduced fatigue and greater efficiency.

The results of this study demonstrate a significant improvement in the participants' 5-meter sprint, 10-meter sprint, and agility performance, attributed to the implementation of high-intensity interval training (Seo et al., 2019). These findings align with the physiological adaptations induced by this training methodology. High-intensity interval training emphasizes repeated bouts of short-duration, high-intensity exercise followed by periods of rest or low-intensity recovery, which elicits substantial neuromuscular and metabolic benefits (Cao et al., 2021). The improvement in sprint performance over short distances is likely due to enhanced neuromuscular coordination and increased recruitment of fast-twitch muscle fibers, which are primarily responsible for explosive movements and rapid accelerations (Seo et al., 2019). Additionally, high-intensity interval training stimulates adaptations in anaerobic energy systems, resulting in increased phosphocreatine stores and improved capacity for energy production during maximal efforts (Ní Chéilleachair et al., 2017). These physiological changes directly enhance the ability to generate force and power in the initial stages of sprinting, leading to faster 5-meter and 10-meter times. Moreover, the repetitive nature of high-intensity efforts contributes to improve motor unit synchronization and firing frequency, which are critical for optimizing sprint mechanics and efficiency (Franchini et al., 2019). The agility improvements observed in the participants are likely a result of enhanced dynamic balance, proprioception, and muscle activation patterns that are systematically developed during high-intensity drills involving rapid changes of direction (Franchini, 2020). High-intensity interval training frequently incorporates multi-directional movements and explosive accelerations, which mimic the demands of agility tasks and promote superior neuromuscular control. The heightened cardiovascular adaptations, including increased stroke volume and oxygen delivery to working muscles, reduce fatigue during repeated sprints and agility movements, thereby enabling sustained high performance (Ní Chéilleachair et al., 2017). These adaptations collectively underpin the observed enhancements in sprint and agility metrics, highlighting the efficacy of high-intensity interval training in targeting the specific physiological and biomechanical demands of these performance components (Mahalingam et al., 2024). One limitation of this study is its relatively short intervention duration of eight weeks, which may not fully capture the long-term physiological adaptations and performance sustainability of High-Intensity Interval Training (HIIT) in adolescent tennis players. Additionally, the sample consisted exclusively of intermediate-level, right-handed male participants from a specific geographic region, potentially limiting the generalizability of the findings to female players, left-handed athletes, or those of different skill levels or cultural contexts. Moreover, the training and testing were conducted without the use of tennis rackets during HIIT, which may not entirely replicate match-specific conditions. By integrating high-intensity interval training into athletic conditioning programs, practitioners can effectively develop the explosive power, speed, and movement efficiency required for success in sports that demand short sprints and quick directional changes (Cao et al., 2021).

Conclusions

This study demonstrates the transformative impact of High-Intensity Interval Training (HIIT) on the physiological and performance metrics of young tennis players. The eight-week structured HIIT intervention led to significant enhancements in maximal oxygen uptake (VO_2 max), jumping ability (CMJ, SJ, DJ), sprint performance (5m and 10m sprint times), and agility. These improvements, evident in the experimental group, highlight the efficacy of HIIT in fostering aerobic and anaerobic adaptations, neuromuscular efficiency, and explosive power, all of which are critical for tennis performance. Conversely, the control group exhibited negligible changes, underscoring the necessity of a structured, high-intensity training regimen for performance optimization. The findings provide robust evidence supporting the integration of HIIT into tennis training programs as a time-efficient and impactful modality. Coaches and practitioners can leverage these insights to design tailored training protocols that enhance athletic performance while minimizing training volume and potential overtraining risks. Future research should explore the long-term sustainability of these benefits and examine the integration of HIIT with sport-specific drills to maximize athlete development. The practical applicability of these findings is substantial for coaches, players, and sports scientists working with tennis athletes, as HIIT offers a time-efficient training methodology that can be integrated into existing programs to optimize aerobic and anaerobic capacities while minimizing training volume and overtraining risks. Tennis coaches can implement sport-specific HIIT protocols during preseason and maintenance phases to enhance player performance across multiple fitness domains simultaneously, while sports scientists can utilize these evidence-based protocols to design periodized training programs that address the intermittent, high-intensity demands of competitive tennis, ultimately supporting both immediate performance gains and long-term athletic development in young tennis players.

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Authors' and translators' details:

Prashant Kumar Choudhary	prashantlnipe2014@gmail.com	Author
Suchishrava Choudhary	suchishrava05@gmail.com	Author
Sohom Saha	sohomsaha77@gmail.com	Translator
Debajit Karmakar	debajitkarmakar2200@gmail.com	Author
Yajuvendra Singh Rajpoot	yajupitu25@gmail.com	Author
Arnav Sharma	arnavsharma164@gmail.com	Author
Sambhu Prasad	sambhu.prasad@rgu.ac.in	Author
Bhanu Pratap	bhanu.dohila27@gmail.com	Author
Dharmendra Singh	gurjardharm@gmail.com	Author
Khushbu Sisodiya	khushbusisodiya.2796@gmail.com	Author
Pradeep Prajapati	prajapatilnipe@gmail.com	Author