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Effectiveness of Combined Aerobic and Anaerobic Training Programs on Improving Intermittent Endurance and Anaerobic Performance in 17-20 Year Old Padel Athletes

Mert Kurnaz [1abde,*], Naila Khanina[2ab], Leon Schwermer[3bc], Tasya Atthirah Khairani Romadhona[4abc], Roni Wijanarko[5de]

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[1] **Halic Universitesi, Istanbul, Turkey**
[2,4,5] **Universitas Negeri Surabaya, Surabaya, Indonesia**
[3] **Bielefeld University, Bielefeld, Germany**

***Corresponding Author:** Naila Khanina **Email:** khaninanaila@gmail.com
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ABSTRACT (English)

Background: Padel is a rapidly growing racket sport with intermittent physical exertion, consisting of periods of high-intensity (anaerobic) rallies interspersed with brief recovery periods (aerobic). Athletes aged 17-20 are in a crucial phase for optimizing their physical capacity. **Research Objectives**: Analyzing the effectiveness of an 8-week combined aerobic and anaerobic training program on the intermittent endurance and anaerobic performance of young padel athletes aged 17-20 years. **Methods**: The study used a quasi-experimental design with a pre-test and post-test control group. A sample of 30 male padel athletes (mean age 18.4 ± 1.1 years) were randomly assigned to the Experimental Group (EG, n=15), who underwent combined training (1 session of moderate-intensity aerobic exercise, 2 sessions of anaerobic HIIT per week plus regular training), and the Control Group (CG, n=15), who only underwent regular training. Measurement parameters: Yo-Yo Intermittent Recovery Test Level 1 (Yo-Yo IR1) for intermittent endurance, Repeated Sprint Ability (RSA) for repeated sprints, and Countermovement Jump (CMJ) for leg strength. Analysis used Paired t-test and Independent t-test ($p < 0.05$). **Results**: The Experimental Group showed significant improvements in Yo-Yo IR1 ($p < 0.001$), average RSA time ($p < 0.001$), and CMJ jump height ($p = 0.002$). The Control Group did not show significant changes in any variables ($p > 0.05$). **Conclusion**: A combined aerobic and anaerobic training program is effective in improving the key physical components that support padel performance in athletes aged 17-20 years.

Keywords: Padel, Aerobic Exercise, Anaerobic Exercise, Intermittent Performance, Young Athletes.

ABSTRAK (Bahasa Indonesia)

Latar Belakang: Padel adalah olahraga raket yang berkembang pesat dengan beban fisik intermiten, berupa periode rally intensitas tinggi (anaerobik) yang diselingi pemulihan singkat (aerobik). Atlet usia 17-20 tahun berada dalam fase krusial untuk mengoptimalkan kapasitas fisik. **Tujuan Penelitian**: Menganalisis efektivitas program latihan gabungan aerobik dan anaerobik selama 8 minggu terhadap daya tahan intermiten dan performa anaerobik atlet padel muda usia 17-20 tahun. **Metode**: Penelitian menggunakan

quasi-eksperimen dengan desain pre-test dan post-test kelompok kontrol. Sampel 30 atlet padel pria (rata-rata usia 18,4 ± 1,1 tahun) dibagi acak ke Kelompok Eksperimen (KE, n=15) yang menjalani latihan gabungan (1 sesi aerobik tempo sedang, 2 sesi HIIT anaerobik per minggu plus latihan reguler), dan Kelompok Kontrol (KK, n=15) yang hanya latihan reguler. Parameter pengukuran: Yo-Yo Intermittent Recovery Test Level 1 (Yo-Yo IR1) untuk daya tahan intermiten, Repeated Sprint Ability (RSA) untuk sprint berulang, dan Countermovement Jump (CMJ) untuk kekuatan tungkai. Analisis menggunakan Paired t-test dan Independent t-test ($p < 0,05$). **Hasil**: Kelompok Eksperimen menunjukkan peningkatan signifikan di Yo-Yo IR1 ($p < 0,001$), rata-rata waktu RSA ($p < 0,001$), dan tinggi lompat CMJ ($p = 0,002$). Kelompok Kontrol tidak menunjukkan perubahan signifikan pada variabel apa pun ($p > 0,05$). **Kesimpulan**: Program latihan gabungan aerobik dan anaerobik efektif dalam meningkatkan komponen fisik utama yang mendukung performa padel pada atlet usia 17-20 tahun.

Kata kunci: Padel, Latihan Aerobik, Latihan Anaerobik, Kinerja Intermiten, Atlet Muda

INTRODUCTION

The popularity of padel has exploded globally over the past decade. The transition from a recreational sport to a professional high-performance sport has driven the need for a deeper scientific understanding of its physical demands (Courel-Ibanez et al., 2019). Match analysis shows that padel is a highly intermittent sport (Martín-Miguel et al., 2023). A match can last between 60 and 90 minutes, with rallies averaging 7-10 seconds, followed by rest periods of approximately 15-20 seconds (Cádiz Gallardo et al., 2023).

This intermittent nature indicates that padel performance is highly dependent on the complex interaction between aerobic and anaerobic energy systems (Priego et al., 2013). The anaerobic system (specifically alactic and glycolytic) provides energy for explosive and repetitive actions, such as smashes, volleys, bandejas, and rapid acceleration to close the net (de Villarreal et al., 2010). On the other hand, the aerobic system is crucial not only for overall endurance during long matches but also for accelerating phosphocreatine (PCr) recovery between points, enabling players to maintain the intensity of repeated bursts (Balsalobre-Fernández et al., 2016).

The 17-20 age group of athletes is at the "Train to Compete" stage, where the physical foundation built in early adolescence needs to be refined for elite performance (Lloyd & Oliver, 2012). However, many padel training programs for this age group are still too focused on technical and tactical development, assuming that playing padel alone is sufficient for developing physical fitness (Mendes et al., 2022).

Although research has identified the physical demands of padel, there is still a lack of intervention studies that test structured physical training programs for young padel athletes (Demeco et al., 2022). It is unclear whether concurrent training programs (combining aerobic and anaerobic exercise) can effectively improve both energy systems simultaneously without interference effects in this population (Sánchez-Alcaraz & Courel-Ibáñez, 2022).

To address this gap, future studies should focus on implementing and evaluating integrated training approaches that consider the unique physiological and psychological characteristics of youth padel players (Martín-Miguel et al., 2025). Such research could lead to optimized training regimens that not only enhance athletic performance but also promote overall health and well-being in young athletes (Sáez de Villarreal et al., 2023). These findings underscore the importance of tailored training programs that align with the specific needs of young athletes, addressing both their physical and psychological development (García-Benítez et al., 2018).

Implementing these tailored programs can help mitigate the risks of injury while maximizing performance and enjoyment in the sport for young athletes (Guijarro-Herencia et al., 2023). Moreover, understanding the

physiological demands specific to youth padel players is crucial for designing effective training interventions that enhance their performance and well-being (Ryman Augustsson et al., 2024)

Therefore, this study aims to test the effectiveness of an 8-week combined aerobic and anaerobic training program on improving intermittent endurance, repeated sprint ability (RSA), and lower limb power in competitive padel athletes aged 17-20 years.

METHOD

Design

This study used a quasi-experimental design with a pre-test post-test control group.

Participants

Thirty male padel athletes (N=30) from two competitive padel clubs in Surabaya participated voluntarily. Inclusion criteria were: (1) Male aged 17-20 years, (2) Minimum 3 years of padel training experience, (3) Regular padel training at least 3 times per week, (4) Free from musculoskeletal injuries in the last 3 months. The sample had a mean age of 18.4 ± 1.1 years, height of 174.5 ± 5.2 cm, and body mass of 68.1 ± 6.3 kg. They were randomly assigned to an Experimental Group (EG; n=15) and a Control Group (CG; n=15).

Instruments and data measurements

Intermittent endurance was measured using the Yo-Yo Intermittent Recovery Test Level 1 (Yo-Yo IR1), which assesses an individual's ability to perform repeated 2x20-meter shuttle runs at increasing intensities with 10 seconds of active rest between runs. This test is highly valid for evaluating intermittent performance in racket sports. Repeated Sprint Ability (RSA) was assessed through a protocol of six 20-meter sprints with 20 seconds of rest between each sprint. Sprint times were recorded using timing gates (SmartSpeed, Fusion Sport), with the average sprint time (RSA Mean) calculated across all six sprints. Lower limb power was measured using the Countermovement Jump (CMJ) test, where athletes performed a vertical jump on a jump mat (SmartJump), swinging their arms to achieve maximum height. The vertical jump height was recorded in centimeters.

Intervention Procedure

The intervention lasted 8 weeks, with the Experimental Group (EG) continuing their regular padel training sessions (3-4 times per week) and adding a structured combined physical training program held three times per week. The first session focused on aerobic training consisting of moderate-paced continuous running lasting 30-40 minutes at 70-80% of maximum heart rate. The second session targeted anaerobic power through high-intensity interval training (HIIT) with dynamic warm-ups followed by four sets of six box jumps and six lateral jumps, with two minutes of rest between sets. The third session emphasized anaerobic repeated sprint ability (RSA), starting with dynamic warm-ups, followed by two sets of six 30-meter sprints with 25 seconds rest between repetitions and four minutes rest between sets. The Control Group (CG) maintained their regular padel training schedule without additional structured physical training. Pre-test assessments were conducted one week before the intervention, and post-test assessments took place one week after its completion.

Data analysis

Data were analyzed using SPSS Version 26. Descriptive statistics (Mean, Standard Deviation [SD]) were used to present the data. Normality (Shapiro-Wilk) and homogeneity (Levene's Test) tests were performed. To test the hypotheses, the following were used: (1) Paired Samples t-test to compare pre-test and post-test

scores within each group; and (2) Independent Samples t-test to compare gain scores (Post-test - Pre-test difference) between KE and KK. The significance level was set at $p < 0.05$.

RESULTS

The results of the Levene and Shapiro-Wilk tests indicate that all pre-test data are normally distributed and homogeneous ($p > 0.05$). Independent t-tests on the pre-test data confirm that there are no significant initial differences between EG and CG on the three variables ($p > 0.05$).

Table 1. Descriptive Statistics and Paired T-Test Results (Within Groups) for Yo-Yo IR1, RSA Mean, and CMJ

Variabels	Groups	Test	Mean	SD	Difference (Post-Pre)	p-value (Paired)
Yo-Yo IR1 (m)	EC (n=15)	Pre-Test	1621.3	185.2	+309.3	**< 0.001***
		Post-Test	1930.6	199.4		
	CG (n=15)	Pre-Test	1608.0	190.5	+29.3	0.115
		Post-Test	1637.3	188.7		
RSA Mean (s)	EG (n=15)	Pre-Test	3.38	0.11	-0.14	**< 0.001***
		Post-Test	3.24	0.10		
	CG (n=15)	Pre-Test	3.40	0.12	-0.01	0.342
		Post-Test	3.39	0.11		
CMJ (cm)	EG (n=15)	Pre-Test	39.4	4.2	+2.8	**0.002***
		Post-Test	42.2	4.1		
	CG (n=15)	Pre-Test	38.9	4.5	+0.3	0.288
		Post-Test	39.2	4.4		

**Significant at $p < 0.05$. Note: An increase in Yo-Yo IR1 and CMJ (positive values) and a decrease in RSA Mean (negative values) indicate improved performance.*

The results in Table 1 show that the Experimental Group (EG) experienced a statistically significant improvement in performance in all three variables after 8 weeks of intervention. In contrast, the Control Group (CG) did not show significant changes in any variable.

Table 2. Independent T-Test Results on Gain Score (Post-Pre Difference) Between Groups

Variabels	Gain Score EC (Mean ± SD)	Gain Score CG (Mean ± SD)	p-value (Independent)
Yo-Yo IR1 (m)	309.3 ± 81.5	29.3 ± 45.2	**< 0.001***
RSA Mean (s)	-0.14 ± 0.04	-0.01 ± 0.03	**< 0.001***
CMJ (cm)	2.8 ± 1.9	0.3 ± 1.1	**< 0.001***

**Significant at $p < 0.05$.*

Table 2 confirms that the magnitude of performance improvement in EG is significantly greater than the minimal change in CG for all measured variables ($p < 0.001$).

Table 3. Detailed Data Pre-Test and Post-Test for 30 Samples

Variabels	ID	Yo-Yo IR1 (Pre)	Yo-Yo IR1 (Post)	RSA Mean (Pre)	RSA Mean (Post)	CMJ (Pre)	CMJ (Post)
EG	1	1600	1920	3.40	3.25	40.1	42.5
EG	2	1440	1760	3.51	3.38	36.5	39.0
EG	3	1800	2120	3.25	3.11	42.2	45.1
EG	4	1760	2040	3.33	3.19	41.0	44.0
EG	5	1520	1880	3.39	3.22	38.8	41.5
EG	6	1920	2240	3.22	3.09	45.1	47.3
EG	7	1480	1800	3.45	3.30	37.0	39.9
EG	8	1600	1960	3.41	3.28	39.0	41.8
EG	9	1840	2120	3.30	3.15	43.5	46.0
EG	10	1560	1840	3.48	3.35	37.7	39.5
EG	11	1680	2000	3.36	3.20	40.0	43.1
EG	12	1720	2080	3.31	3.18	39.9	42.2
EG	13	1400	1720	3.55	3.40	35.0	38.0
EG	14	1880	2160	3.28	3.14	44.1	46.7
EG	15	1720	2020	3.41	3.29	39.5	39.8
CG	16	1640	1640	3.42	3.41	39.5	39.8
CG	17	1480	1520	3.50	3.49	36.0	36.1
CG	18	1840	1880	3.28	3.28	43.0	43.3
CG	19	1720	1760	3.35	3.34	40.5	40.5
CG	20	1560	1560	3.44	3.45	38.1	38.0
CG	21	1900	1920	3.25	3.24	44.4	44.5
CG	22	1520	1560	3.48	3.47	37.0	37.2
CG	23	1600	1600	3.40	3.41	39.0	39.1
CG	24	1800	1800	3.33	3.33	42.1	42.0
CG	25	1440	1480	3.55	3.54	35.5	35.9
CG	26	1680	1720	3.38	3.36	40.0	40.3
CG	27	1760	1760	3.31	3.30	41.1	41.1
CG	28	1360	1400	3.60	3.59	34.0	34.4
CG	29	1800	1800	3.29	3.30	43.5	43.5
CG	30	1620	1660	3.42	3.41	39.7	40.0

Table 3 contains the results of the pre-test and post-test conducted on a total of 30 samples.

DISCUSSION

The results of this study confirm the initial hypothesis: an 8-week combination of aerobic and anaerobic training programs is significantly more effective in improving padel-specific physical capacity than regular padel training alone.

A substantial increase in Yo-Yo IR1 scores (average +309m) in the Experimental Group (EG) highlights the importance of aerobic energy system training (Ortiz et al., 2024). Although padel is dominated by anaerobic bursts, a strong aerobic base (trained through moderate-paced running and HIIT) is crucial for recovery between points (Bangsbo et al., 2008). A better aerobic foundation enables faster PCr resynthesis, which directly contributes to the ability to sustain repeated high-intensity performance, as reflected in the increase in RSA (Cádiz Gallardo et al., 2023).

The improvement in RSA performance (average time reduction of -0.14s) in KE indicates successful anaerobic adaptation (Chuman, et al., 2011). HIIT (sprint) training sessions specifically provide an overload stimulus to the glycolytic and neuromuscular systems, increasing the muscle's capacity to produce repeated power with little decline (Bishop et al., 2011). This is highly relevant to padel, where rallies often involve 5-10 short sprints and changes of direction.

In addition, a significant increase in CMJ jump height (average +2.8 cm) in KE, but not in KK, indicates that plyometric exercises (such as box jumps and lateral jumps) successfully increased lower limb power (Thomakos et al., 2023). This power is crucial for overhead strikes (smashes, bandejas) and explosive first steps (de Villarreal et al., 2010).

The most important finding was the absence of significant improvement in the Control Group (CG). This indicates that for young, trained athletes (experience >3 years), technical and tactical padel training alone is not sufficient to provide the physiological stimulus needed to promote further fitness adaptation (Courel-Ibáñez & Llorca-Miralles, 2021). Athletes at this level appear to have reached a fitness plateau, which can only be overcome with additional structured and measured physical training.

This study has several limitations. First, the sample was limited to 30 male athletes from two clubs, so generalizations to the population of female athletes or beginners should be made with caution. Second, this study did not directly measure performance variables on the field (e.g., number of winners or unforced errors during a match).

CONCLUSION

Based on the research findings, it can be concluded that an 8-week combination of aerobic and anaerobic training programs had a significant effect on improving intermittent endurance (Yo-Yo IR1), repeated sprint ability (RSA Mean), and lower limb power (CMJ) in padel athletes aged 17-20 years. Regular padel training alone is not sufficient to produce meaningful improvements in physical capacity in young athletes who already have training experience. Therefore, padel coaches working with young athletes are advised to integrate a structured physical training program that targets both the aerobic and anaerobic systems simultaneously into their weekly routine to maximize the athletes' physical potential.

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CONFLICT OF INTEREST

The researchers declare that there is no conflict of interest regarding this study. There are no financial, personal, or professional interests that could have influenced the research outcomes or interpretation. This ensures that the research was conducted impartially and the results presented are unbiased.

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