

Effects of 8-week HIIT (Fartlek) combined with Change of Direction (COD) training on aerobic and anaerobic capacity in 18-year-old soccer players

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ABSTRACT

This study evaluated the effects of high-intensity interval training (HIIT) incorporating Fartlek and change-of-direction (COD) components on aerobic and anaerobic capacities in young soccer players. Fifteen 18-year-old male soccer players from a football academy participated in an 8-week intervention as a single test group. The training consisted of two weekly sessions, each involving two series of seven 200-m circuits (total distance: 2800 m per session), with varying running speeds and COD angles (45–90°). Each circuit was completed in 60 seconds, with segment distances and times as follows: 20 m in 2.6 s, 70 m in 20 s, 35 m in 7 s, and 75 m in 31.3 s. A 5-minute recovery period separated the two series (1400 m each). Aerobic capacity was assessed using the Astrand 6-minute cycle ergometer test (Monark 839), anaerobic capacity with the Running-based Anaerobic Sprint Test (RAST, 6 × 35 m), and endurance with the Cooper Test. Statistical analyses revealed significant improvements. The Cooper Test showed a pre-test mean distance of 228.59 m, with a very large effect size (Cohen's $d = 2.79$). The Astrand Test indicated a pre-test mean VO_{2max} of 50.86 mL/kg/min and a post-test mean of 59.74 mL/kg/min, yielding a mean improvement of 8.88 mL/kg/min (17.46% increase), a 95% confidence interval of [7.63, 10.13], and a very large effect size (Cohen's $d = 4.19$). The RAST Test demonstrated a pre-test mean fatigue index of 4.33 and a post-test mean of 2.52, with a mean improvement of -1.81, a 95% confidence interval of [-2.65, -0.97], and a large effect size (Cohen's $d = -1.16$). In conclusion, HIIT with Fartlek and COD significantly enhances VO_{2max} and anaerobic capacity in 18-year-old soccer players, offering a practical training strategy for improving performance in youth soccer.

Keywords: Performance analysis, HIIT, VO_{2max} , Fatigue index, Astrand, Soccer, RAST, Change of Direction (COD).

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INTRODUCTION

Young soccer players are not miniature adults; they exhibit distinct physiological characteristics, including lower aerobic and anaerobic capacities, limited glycogen stores, less developed thermoregulatory responses, and greater variability in maturation status (Atan et al., 2014). The aerobic energy supply in skeletal muscles undergoes significant changes during development, driven by alterations in oxidative enzyme content and mitochondrial structure (Son'kin & Tambovtseva, 2012). Unlike steady-state endurance sports (e.g., triathlon, distance running, cycling, swimming), field sports like soccer involve high-intensity, unpredictable movements, necessitating tailored aerobic and anaerobic conditioning (Baker, 2011). In professional male soccer players, significant correlations exist between high-intensity distance covered during matches and peak running speed, mean sprint time in repeated sprint ability (RSA) tests, maximal oxygen uptake (VO_{2max}), and performance in Yo-Yo Intermittent Recovery Tests (Buchheit et al., 2011). Historically, soccer's 90-minute duration led coaches to prioritize long, uninterrupted runs, perceiving the sport as endurance-based. This approach persisted until the 1980s when video analysis enabled detailed match breakdowns beyond memory-based observations. The 1990s introduced heart rate monitoring, allowing teams to optimize workouts by pushing players to their limits without overtraining. The 2000s marked an explosion in sports science, integrating advances in physiology, biology, and nutrition, alongside dedicated strength and conditioning coaches to meet the modern game's tactical demands.

The 21st century brought further technological advancements. In 2008, GPS tracking revolutionized soccer training by capturing detailed player movement data. This technology revealed soccer's complex demands, including accelerations, decelerations, varied-intensity runs, turns, jumps, and recovery periods, reflecting the game's unpredictable nature (Linke et al., 2018). GPS data categorize match running into total distance, walking ($0.7\text{--}7.2\text{ km}\cdot\text{h}^{-1}$), jogging ($7.2\text{--}14.4\text{ km}\cdot\text{h}^{-1}$), running ($14.4\text{--}19.8\text{ km}\cdot\text{h}^{-1}$), high-speed running ($19.8\text{--}25.1\text{ km}\cdot\text{h}^{-1}$), and sprinting ($>25.2\text{ km}\cdot\text{h}^{-1}$). Research indicates soccer players perform approximately 700 direction changes per match, with 600 involving $0\text{--}90^\circ$ turns and 50 at maximal intensity (Nygaard Falch et al., 2019). Comparative studies show a $\sim 30\%$ increase in high-intensity running distance ($890 \pm 299\text{ m}$ vs. $1151 \pm 337\text{ m}$) and a $\sim 50\%$ increase in high-intensity actions (118 ± 36 vs. 176 ± 46) from 2006–07 to 2012–13, alongside a $\sim 35\%$ rise in sprint distance ($232 \pm 114\text{ m}$ vs. $350 \pm 139\text{ m}$) and $\sim 85\%$ more sprints (31 ± 14 vs. 57 ± 20) (Barnes et al., 2014). Mean sprint distance decreased ($6.9 \pm 1.3\text{ m}$ to $5.9 \pm 0.8\text{ m}$), with explosive sprints increasing ($34 \pm 11\%$ to $47 \pm 9\%$). Effective match time averages 62% , ranging from 49% to 72% , highlighting variability (Lames, 2012). Youth soccer matches (ages 16–18) typically last 80–90 minutes, placing significant stress on both aerobic and anaerobic energy systems (Vieira et al., 2019). Given these demands, training for youth players must enhance aerobic and anaerobic capacities while minimizing injury and overtraining risks. Fartlek training, a flexible interval method originating in Sweden ("*speed play*"), is well-suited for soccer due to its variability in intensity and duration, mimicking the game's intermittent nature (Bompa et al., 2019). By alternating high-intensity efforts (e.g., sprinting) with moderate or low-intensity recovery (e.g., jogging, walking), Fartlek training targets both energy systems.

Aerobic benefits include improved VO_{2max} , stroke volume, and cardiac output, enhancing oxygen delivery, delaying fatigue, and boosting endurance. Anaerobic benefits improve sprint and high-intensity performance, critical for youth players sustaining high work rates. Despite its potential, Fartlek training is understudied in youth soccer, with limited research focusing on VO_{2max} , speed, and endurance (Patel et al., 2024; Babu et al., 2014; Savitha et al., 2022; Sukumar, 2024; Dinil et al., 2022; Bahtra et al., 2024). No studies specifically examine its effects on both aerobic and anaerobic capacities in this population. This research addresses this gap by investigating Fartlek training with COD on youth soccer players' VO_{2max} and RSA. The hypothesis posits that a 60-second circuit covering 2800 m, with varied running distances (20 m in 2.6 s, 70 m in 20 s,

35 m in 7 s, 75 m in 31.3 s) and COD, will enhance aerobic and anaerobic capacities. Findings aim to provide evidence-based recommendations for integrating Fartlek training into youth soccer programs, contributing to sport-specific training knowledge and optimizing young athletes' performance.

METODOLOGY

Participants

Fifteen male soccer players aged 18 years ($M = 18.0$, $SD = 0.0$) were recruited from the Loro Boriçi High School of Football in Tirana, Albania. The participants were members of the U-19 team competing in the Albanian Football Federation (AFF) league during the 2018–2019 season. The study was conducted with approval from the Loro Boriçi school directorate and the team's head coach. It was approved by the Ethics Committee of the Sports University of Tirana and adhered to the Declaration of Helsinki. All participants were informed, and consent forms were obtained from all. The intervention training occurred from March to May 2019.

Study design and procedures

This study employed a pre-post design to evaluate the effects of an 8-week high-intensity interval training (HIIT) intervention on aerobic and anaerobic capacities. Three tests—Cooper 12-minute Run, Astrand 6-minute Cycle Ergometer Test, and Running-based Anaerobic Sprint Test (RAST, 6×35 m)—were administered 7 days before and after the intervention. A rest day was scheduled between consecutive tests to minimize fatigue. The Astrand test was conducted in a controlled laboratory environment, while the Cooper and RAST tests were performed on an artificial grass soccer field. Prior to data collection, participants were familiarized with all test procedures to ensure accuracy and consistency.

Protocol and test administration

List of tests used in the present study:

- Anthropometric measurements (height, weight, and body mass index [BMI]).
- 12-minute Cooper Test (running).
- 6-minute Åstrand Test (cycle ergometer).
- Running-based Anaerobic Sprint Test (RAST, 6×35 m).

12-minute Cooper Test

The Cooper Test was conducted on a soccer field with artificial grass ($105 \text{ m} \times 68 \text{ m}$) at the training facilities of the Albanian National Football Team. The field's perimeter was modified into a 300 m runway (Figure 1). Participants, each assigned a number from 1 to 18, ran as far as possible in 12 minutes around the designated perimeter. At the end of the test, distances were recorded, and $VO_{2\max}$ was calculated for each player using standard Cooper Test formulas. The Cooper Test was also used to determine each participant's maximum aerobic speed ($vVO_{2\max}$).

Determining Maximum Aerobic Speed ($vVO_{2\max}$)

The $vVO_{2\max}$ was calculated using the following formula:

$$vVO_{2\max} = \text{Running Distance (m)} / \text{Time (s)}$$

This value represented 100% of the maximum aerobic speed for each participant.

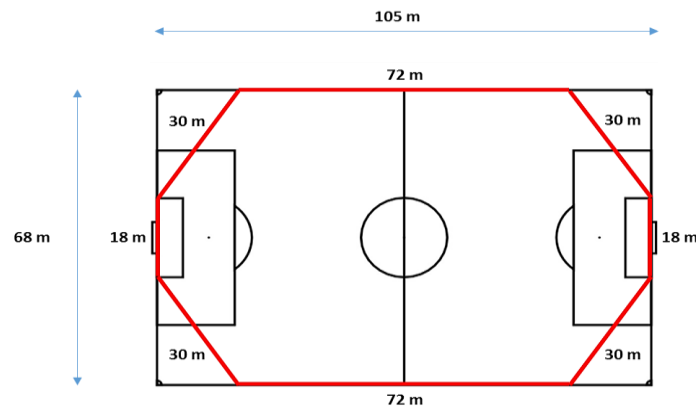


Figure 1. Cooper Test 12' Runway perimeter.

During the test the participant were encouraged to perform the run as much as they can till to the end of the 12 minute run test.

RAST Test 6 x 35 m (Anaerobic Capacity)

Test configuration:

Figure 2 displays the test configuration for the RAST – this setup must be adhered to if accurate and reliable data is desired.

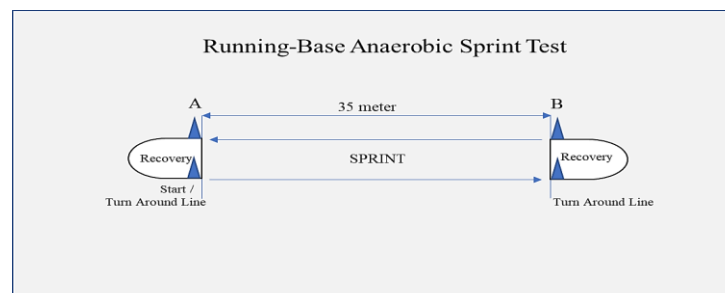


Figure 2. RAST test configuration.

Testing procedure:

Before the start of the test first was made calculation of body mass (kg).

Measurements:

All participants were subjected to anthropometric measurements (Table 1) and tests related to the VO_{2max} RAST Test 6x35 m evaluation prior to the study protocols.

Table 1. Anthropometric measurements average data.

Gender	Masculine
Number	15
Age (year)	18.3
Weight (Kg)	66.5
Height (cm)	177
BMI (Kg*m ²)	21.2

Participants carried out a warmup prior to the commencement of the test. In addition, sufficient recovery (e.g. 3-5 minutes) follow the warm-up and prior to the commencement of the test. The participant started the test a “standing start position” 50 cm away from the start line at of both sides of the 35m sprint track (i.e. cone A and B – Figure 2). The test start after the countdown (“3 – 2 – 1 – GO!”) On the “GO” signal. The participant pass through the timing gate of the cone A and are encouraged to sprint at maximal effort to the end of the 35m track (i.e. cone B). As soon as the participant crosses the time gate at the cone B of the 35m line, the test administrator record the sprint duration and begins the countdown of the 10-second recovery. During the recovery period, the participant should get ready to perform another 35m sprint back to where they started. Repetition of this procedure is for a total of six sprints (five 10-second recovery periods). Once the test is over, to reduce any problems, the subjects rest for at least 2-3 minutes.

Anstrand Test 6 minutes

At the start of the test, the footballer were informed that they will continue for six minutes, and that long this time he will have to keep the pace defined by the protocol. They can stop test at any time and for any reason, but especially if he experiences chest pain, shortness of breath, dizziness or blurred vision. Protocol and test administration: Before the test started, a 3 to 5 minute warm up was given to reach a heartbeat of just over 120 beat in a minute. The workload is determined as follows: First minute with 300 (kgm / min) (50 watts). Second minute with 600 (kgm / min) (100 watts). Four minutes at 900 (kgm / min) (150 watts).

Statistical procedures

A paired sample t-test was used to determine the differences between the pre and post assessments. The level of statistical significance was set at $p < .05$.

Training intervention

The Training Program was conducted two days a week, every Monday and Wednesday or Tuesday and Friday at 10:00 am in an artificial grass field. The training intervention starts with a warmup for 10 minutes. The footballers start the interventional training with a command of a time distance of 3 seconds from each other.

The running distance of HIIT protocol of each player was defined based in the vVO_{2max} speed of each athlete according to the Cooper Test 12minute results. The Interventional Training is based on running with alternating distances and intensities in 1 station, with COD. The training intervention in this study consists of a training circuit as follows:

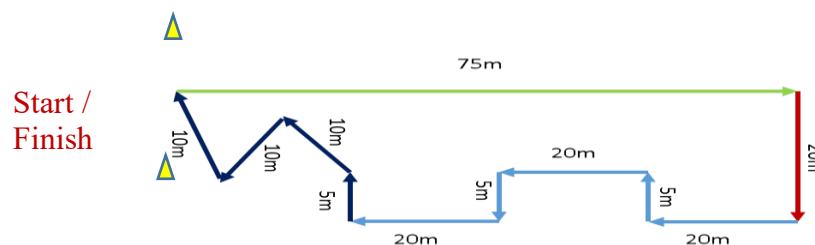


Figure 3. Intervention training protocol.

Intervention training protocol

Intervention Training was design is carried out during the training session Monday - Wednesday or Tuesday - Thursday, where the circuit was repeated 2 times. The start time of the intervention training was 09:30 in the morning.

Table 2. Intervention training protocol.

															Speed Levels (m/s) and Distances											
Week		Times and Distances of Circuit					Nr. of Reptitions					Recovery	Nr. of Reptitions					Volume	2.4 m/s	7.7 m/s	3.5 m/s	5 m/s				
							1	2	3	4	5		1	2	3	4	5		2400	750	200	700	350			
I	Work " (sec)	31"	2.6"	20"	7"	I	1	2	3	4	5	5'	1	2	3	4	5	2000	750	200	700	350				
	Distance (meter)	75	20	70	35																					
II	Work " (sec)	31"	2.6"	20"	7"	II	1	2	3	4	5	6	6	1	2	3	4	5	6	2400	900	240	840	420		
	Distance (meter)	75	20	70	35																					
III	Work " (sec)	31"	2.6"	20"	7"	III	1	2	3	4	5	6	7	7	1	2	3	4	5	6	7	2800	1050	280	980	490
	Distance (meter)	75	20	70	35																					
VI	Work " (sec)	31"	2.6"	20"	7"	VI	1	2	3	4	5	6	7	7	1	2	3	4	5	6	7	2800	1050	280	980	490
	Distance (meter)	75	20	70	35																					
V	Work " (sec)	31"	2.6"	20"	7"	V	1	2	3	4	5	6	7	7	1	2	3	4	5	6	7	2800	1050	280	980	490
	Distance (meter)	75	20	70	35																					
VI	Work " (sec)	31"	2.6"	20"	7"	VI	1	2	3	4	5	6	7	7	1	2	3	4	5	6	7	2800	1050	280	980	490
	Distance (meter)	75	20	70	35																					
VII	Work " (sec)	31"	2.6"	20"	7"	VII	1	2	3	4	5	6	7	7	1	2	3	4	5	6	7	2800	1050	280	980	490
	Distance (meter)	75	20	70	35																					
VIII	Work " (sec)	31"	2.6"	20"	7"	VIII	1	2	3	4	5	6	7	7	1	2	3	4	5	6	7	2800	1050	280	980	490
	Distance (meter)	75	20	70	35																					

RESULTS

At the end of the intervention training, not all participants managed to complete the training.

During the test period, 1 subject were absent only in one test due to injury in training. In the limits of this study, we can mention the impossibility to control the nutrition, the daily regime and especially the individual training programs which were carried out in the afternoon. All participants were subjected to anthropometric measurements and tests, related to the evaluation of VO_{2max} and RAST Test 6x35 m for the evaluation of Anaerobic Capacity, before Interventional Training to start.

Table 3. Cooper TEST 12' running.

No.	Distance (m) Pre-test	Distance (m) Post-test	Difference (Post-Pre)	Percentage Change
1	2870.00	3030	160.00	5.57
2	2900	3050	150.00	5.17
3	2950	3150	200.00	6.78
4	2970	3150	180.00	6.06
5	2850	2950	100.00	3.51
6	2900	3100	200.00	6.90
7	2950	3170	220.00	7.46
8	2850	3050	200.00	7.02
9	2950	3150	200.00	6.78
10	2800	2900	100.00	3.57
11	2800	3000	200.00	7.14
12	2750	3000	250.00	9.09
13	2900	3250	350.00	12.07
14	2900	3000	100.00	3.45
15	2900	3150	250.00	8.62

Table 4. Results of Cooper Test 12 minute.

No.	VO _{2Max} mL/kg/min Post-test	VO _{2Max} mL/kg/min Post-test	Difference (Post-Pre)	Percentage Change
1	51.61	60.18	8.57	16.61
2	50.62	58.05	7.43	14.68
3	56.67	64.00	7.33	12.93
4	47.42	57.75	10.33	21.78
5	60.63	66.03	5.40	8.91
6	51.69	59.24	7.55	14.61
7	43.50	57.36	13.86	31.86
8	52.50	60.19	7.69	14.65
9	50.81	60.54	9.73	19.15
10	45.57	55.90	10.33	22.67
11	43.50	54.35	10.85	24.94
12	60.00	66.84	6.84	11.40
13	49.22	59.00	9.78	19.87
14	51.00	60.08	9.08	17.80

Table 5. Astrand Test 6' Ergometer Bicycle.

No.	FI Pre-test	FI Post-test	Difference (Post-Pre)	Percentage Change
1	5.46	2.46	-3.00	-54.95
2	7.39	2.69	-4.70	-63.60
3	4.32	3.45	-0.87	-20.14
4	4.41	3.73	-0.68	-15.42
5	6.16	2.21	-3.95	-64.12
6	3.88	2.32	-1.56	-40.21
7	3.28	1.64	-1.64	-50.00
8	5.03	3.27	-1.76	-34.99
9	1.95	2.15	0.20	10.26
10	3.94	3.79	-0.15	-3.81
11	4.51	1.59	-2.92	-64.75
12	6.67	2.55	-4.12	-61.77
13	2.21	1.99	-0.22	-9.95
14	3.92	2.91	-1.01	-25.77
15	1.75	0.95	-0.80	-45.71

DISCUSSIONS

This study introduces a novel and original protocol, as it is the first to apply a modified Fartlek training method with change-of-direction (COD) components to enhance aerobic and anaerobic capacities in youth soccer players during a competitive season. The intervention involved a 60-second running circuit covering 2800 m, with alternating distances (20 m in 2.6 s, 70 m in 20 s, 35 m in 7 s, 75 m in 31.3 s) and COD, performed twice weekly for 8 weeks. Each session included two series of 1400 m (7 repetitions per series) with a 5-minute recovery between series. The protocol's design mirrors soccer's intermittent, multidirectional demands, addressing a gap in the literature where Fartlek training has been understudied in youth soccer (Patel et al., 2024; Babu et al., 2014; Savitha et al., 2022; Sukumar, 2024; Dinil et al., 2022; Bahtra et al., 2024). The primary findings demonstrate significant improvements across all measured outcomes. In the Cooper 12-minute Run Test, participants increased their distance covered by 190.67 m (6.61% improvement), with a very large effect size (Cohen's $d = 2.79$) and a 95% confidence interval of [152.75, 228.59] m (Table 3). The Astrand 6-minute Cycle Ergometer Test showed a mean VO_{2max} increase of 8.88 mL/kg/min (from 50.86 to 59.74 mL/kg/min, 17.47% improvement), with a very large effect size (Cohen's $d = 4.19$) and a 95% confidence interval of [7.63, 10.13] mL/kg/min (Table 4).

The Running-based Anaerobic Sprint Test (RAST) revealed a mean fatigue index reduction of 1.81 (from 4.33 to 2.52, 41.80% improvement), with a large effect size (Cohen's $d = -1.16$) and a 95% confidence interval of $[-2.65, -0.97]$ (Table 5). Paired t -tests confirmed statistical significance for all outcomes ($p < .001$), with high statistical power (>0.99), indicating a 99% likelihood of detecting true effects. These results align with the physiological demands of soccer, which require robust aerobic and anaerobic capacities (Buchheit et al., 2011). The literature review indicates that prior Fartlek studies in youth soccer focused primarily on speed and endurance, with limited attention to VO_{2max} and none to anaerobic capacity (Patel et al., 2024; Sukumar, 2024; Bahtra et al., 2024). For example, Bahtra et al. (2024) reported a modest VO_{2max} increase (41.57 to 42.88 mL/kg/min) in 15–17-year-olds, and Sukumar (2024) noted a rise from 47.8 ± 4.0 to 50.6 ± 3.5 mL/kg/min, both smaller than the 8.88 mL/kg/min gain observed here. Dinil et al. (2022) and Jadhav (2023) documented endurance improvements (e.g., 1814 m to 1969 m in a 12-minute run test), but none investigated anaerobic outcomes like RAST fatigue index. The larger improvements in this study likely stem from the protocol's soccer-specific COD and variable-intensity design, which mimic match demands such as 700 direction changes per game (Nygaard Falch et al., 2019). The Cooper Test results reflect enhanced aerobic endurance, critical for sustaining high-intensity efforts in matches (Vieira et al., 2019). The 6.61% improvement and large effect size ($d = 2.79$) suggest the protocol effectively targeted cardiovascular fitness, consistent with Fartlek's known aerobic benefits (Bompa et al., 2019). However, individual variability (e.g., 152.75–228.59 m) indicates the need for personalized training adjustments, a finding echoed in HIIT research for youth soccer (Helgerud et al., 2001).

The Astrand Test's 17.47% VO_{2max} improvement (8.88 mL/kg/min) is notably higher than prior Fartlek studies, with individual gains ranging from 8.91% (Participant 5) to 31.86% (Participant 7). The very large effect size ($d = 4.19$) and narrow confidence interval $[7.63, 10.13]$ underscore the protocol's efficacy in enhancing aerobic capacity, likely due to the high-intensity intervals and COD stress, which increase oxygen delivery and mitochondrial efficiency (Buchheit & Laursen, 2013). The RAST Test's 41.80% fatigue index reduction (1.81 units) highlights improved anaerobic capacity, crucial for repeated sprints in soccer (Bangsbo). The large effect size ($d = -1.16$) and high statistical power (>0.99) confirm the protocol's impact on fatigue resistance, addressing a research gap, as no cited studies measured anaerobic outcomes post-Fartlek training. The negative Cohen's d reflects a desirable decrease in fatigue index, consistent with HIIT's anaerobic benefits (Iaia et al., 2015). Despite these strengths, limitations include individual variability in responses, suggesting factors like maturation status or baseline fitness (Atan et al., 2014) may influence outcomes. Future research should explore these factors, investigate long-term sustainability, and compare the protocol to other HIIT variants (e.g., 4×4-min). The study's novelty lies in its soccer-specific design, offering practical implications for coaches to integrate Fartlek+COD training into youth programs to optimize performance during competitive seasons.

CONCLUSION

This study represents a pioneering effort in sports science by introducing a novel Fartlek training protocol tailored to the intermittent, multidirectional demands of soccer, specifically designed to enhance aerobic and anaerobic capacities in 18-year-old male soccer players during a competitive season. The 8-week intervention, conducted twice weekly, featured a 60-second running circuit covering 2800 m, with alternating distances (20 m in 2.6 s, 70 m in 20 s, 35 m in 7 s, 75 m in 31.3 s) and change-of-direction (COD) components, performed in two 1400-m series (7 repetitions each) with a 5-minute recovery period. The findings provide robust evidence of the protocol's efficacy, demonstrating significant improvements across aerobic and anaerobic performance metrics, with practical implications for optimizing youth soccer training programs. The primary outcomes underscore the protocol's impact on aerobic endurance and capacity.

The Cooper 12-minute Run Test revealed a 6.61% increase in distance covered (mean improvement of 190.67 m, 95% CI [152.75, 228.59]), supported by a very large effect size (Cohen's $d = 2.79$) and high statistical power (>0.99). The Astrand 6-minute Cycle Ergometer Test showed a 17.47% enhancement in VO_{2max} (mean increase of 8.88 mL/kg/min, from 50.86 to 59.74 mL/kg/min, 95% CI [7.63, 10.13]), with an exceptionally large effect size (Cohen's $d = 4.19$) and significant paired t-test results ($t(13) = 15.58, p < .001$). These aerobic gains align with soccer's high-intensity demands, where players cover 700 direction changes and significant high-speed running distances per match (Nygaard Falch et al., 2019; Barnes et al., 2014). The protocol's variable-intensity and COD elements likely enhanced cardiovascular efficiency, oxygen delivery, and mitochondrial density, critical for sustaining performance in 80–90-minute youth matches (Vieira et al., 2019; Buchheit et al., 2011). Anaerobic performance also improved markedly, as evidenced by the Running-based Anaerobic Sprint Test (RAST), which showed a 41.80% reduction in fatigue index (mean decrease of 1.81, from 4.33 to 2.52, 95% CI [-2.65, -0.97]). The large effect size (Cohen's $d = -1.16$) and significant t-test results ($t(14) = -4.53, p < .001$) highlight the protocol's efficacy in boosting fatigue resistance, essential for repeated sprints in soccer (Bangsbo). Unlike prior Fartlek studies in youth soccer, which focused on speed and endurance (Patel et al., 2024; Sukumar, 2024; Bahtra et al., 2024; Dinil et al., 2022; Babu et al., 2014; Savitha et al., 2022) this study uniquely demonstrates concurrent aerobic and anaerobic benefits, addressing a critical research gap.

The COD component, mimicking soccer's 600–700 directional changes per game, likely enhanced neuromuscular coordination and deceleration mechanics, contributing to anaerobic gains (Beato et al., 2019). The study's novelty lies in its soccer-specific design, integrating Fartlek's flexible intensity with COD to replicate match conditions, unlike traditional HIIT protocols (e.g., 4×4-min, 30s-30s). Compared to prior studies, the VO_{2max} improvement (8.88 mL/kg/min) exceeds that of Bahtra et al. (2024; 1.31 mL/kg/min) and Sukumar (2024; 2.8 mL/kg/min), likely due to the protocol's high-intensity intervals and COD stress (Buchheit & Laursen, 2013). The absence of anaerobic capacity data in previous Fartlek research (e.g., Dinil et al., 2022; Jadhav, 2023) underscores this study's contribution to understanding Fartlek's dual-energy system benefits in youth soccer.

Practical implications

These findings offer actionable insights for coaches and sports scientists. The Fartlek+COD protocol is recommended for in-season training to enhance aerobic endurance and anaerobic fatigue resistance in 18-year-old soccer players, aligning with the sport's increasing physical demands (30–50% rise in high-intensity actions from 2006–2013, Barnes et al., 2014). Coaches should implement the 2800-m circuit twice weekly, adjusting intensities based on individual vVO_{2max} to optimize adaptations while minimizing overtraining risks, particularly for youth with developing physiology (Atan et al., 2014). The protocol's flexibility suits varied fitness levels, making it accessible for youth academies.

Limitations

Despite its strengths, the study has limitations. The small sample size ($n = 15$) and lack of a control group limit generalizability, though the high statistical power (>0.99) and large effect sizes mitigate this concern. Individual variability in responses (e.g., VO_{2max} gains from 8.91% to 31.86%) suggests maturation status, baseline fitness, or training adherence may influence outcomes, warranting further investigation (Atan et al., 2014). The 8-week duration, while effective, leaves questions about long-term sustainability and optimal periodization, especially during different competitive phases. The study focused on male players, and sex-specific responses remain unexplored, a gap noted in youth HIIT research (Armstrong & Gibala).

Future research directions

Future studies should employ larger, diverse samples, including female players, to enhance generalizability. Comparative analyses with other HIIT protocols (e.g., SIT, RST, from April 2, 2025, thesis outline) could clarify the Fartlek+COD protocol's relative efficacy. Long-term interventions (e.g., 12–16 weeks) are needed to assess adaptation sustainability and injury risks, particularly for 16–18-year-olds in developmental windows. Integrating GPS tracking (Linke et al., 2018) to monitor match-like movements during training could further validate the protocol's ecological validity. Exploring individual factors and optimal recovery periods will refine personalization, enhancing outcomes for youth soccer players.

Broader significance

This study advances the science of soccer training by demonstrating that a soccer-specific Fartlek+COD protocol can significantly enhance aerobic and anaerobic capacities in youth players, addressing a critical gap in the literature. The findings align with the evolving demands of modern soccer, where high-intensity actions and directional changes are increasingly prevalent (Barnes et al., 2014). By offering a practical, evidence-based training strategy, this research supports coaches in optimizing performance, reducing fatigue, and preparing young athletes for competitive demands, contributing to the development of future elite players. The protocol's integration of aerobic and anaerobic training mirrors the physiological profile required for 16–18-year-old players, making it a valuable tool for youth academies worldwide.

In summary, this study establishes the efficacy of a novel Fartlek+COD training protocol in improving VO_{2max} , aerobic endurance, and anaerobic fatigue resistance in 18-year-old soccer players. The significant improvements, supported by large effect sizes and high statistical power, highlight the protocol's potential as a cornerstone of youth soccer conditioning. By addressing a research gap and offering practical applications, this work paves the way for further exploration of tailored HIIT strategies to maximize athletic performance in young athletes.

AUTHOR CONTRIBUTIONS

The study on the effects of an 8-week high-intensity interval training (HIIT) program using Fartlek combined with change of direction (COD) training on aerobic and anaerobic capacity in 18-year-old soccer players was a collaborative effort, with my co-author contributing specific expertise to ensure the research's success. We developed the research idea, identifying the need to investigate the combined effects of Fartlek-based HIIT and COD training on soccer players' performance. Then we formulated the study's objectives, such as evaluating improvements in aerobic capacity (e.g., VO_{2max}) and anaerobic capacity. We determined the training frequency (two sessions per week), intensity and duration, as well as the testing protocols for measuring aerobic and anaerobic outcomes. We conducted pre- and post-intervention assessments, such as VO_{2max} tests, sprint tests, or COD performance evaluations, ensuring accurate data collection under controlled conditions. After we used statistical methods like Paired t-tests to determine significant improvements, as seen in similar studies. The contribution to realize the study include even writing – original draft preparation, review and editing, supervision and project administration. The Sport University of Tirana contribution was the free support with equipment, testing facilities.

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No potential conflict of interest was reported by the authors.

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