International Journal of Religion
2024
Volume: 5| Number 3 | pp. 221 – 229
ISSN: 2633-352X (Print) | ISSN: 2633-3538 (Online)
ijor.co.uk
DOI: https://doi.org/10.61707/k8bwcq46

Recovery After High-Intensity Interval Training in Professional Soccer Players: Passive-Active Combination Recovery Technique

Esin GÜLLÜ[1] and Abdullah GÜLLÜ[2]

Abstract

Objective: The aim of this study is to investigate which of the passive recovery (PR), active recovery (AR) and passive-active combination recovery (PAR) techniques applied after the end of high-intensity interval training (HIIT) was more effective in professional super league soccer players. Method: 28 trained professional male soccer players (age: 24.79±2.75 years, height: 180.50±5.81 cm, weight: 74.18±5.47 kg) from the Türkiye Super League team participated in this study voluntarily. Before the study, participants were assigned to 3 groups according to heart rate (HR) and lactic acid (La) levels. Each HIIT load intensity was determined according to the Karvonen method. HIIT sessions were performed for 5 repetitions of 2 minutes (1 set = 5x2 minutes) and a 30-second rest was given between repetitions. At the end of the set, a 2-minute recovery period was applied. Three different recovery techniques, PR, AR and PAR, were applied alternately to each group at the end of the HIIT programs. Participants' HR and La values were taken at the end of HIIT and recovery techniques. Differences between the obtained data were determined by repeated measures one-way ANOVA and multiple comparison tests. P<0.05 level was considered significant in all tests. Results: Although there was no significant difference in La levels between groups (p>0.05), significant differences were observed between HR and loading intensities (p<0.05). According to the results of multiple comparisons, the recoveries in HR and La levels were found to be significant in favor of the PAT group (p<0.05). Discussion: It can be thought that football players increase the mitochondrial biogenesis, oxidative and lipid oxidation capacities of skeletal muscles due to adaptations to HIIT and similar heavy workouts. Depending on these developments in the athletes' condition, it can be said that all three recovery techniques affect the decrease of HR and La in the two-minute period. Conclusion: PR and PAR techniques were effective in reducing HR levels. AR and PAR techniques were effective in reducing La levels. Therefore, it can be said that the PAR technique is more effective in reducing both HR and La levels together.

Keywords: *Soccer, High-Intensity Interval Training, Heart Rate, Blood Lactate Level, Recovery Technique, Professional Soccer Player*

INTRODUCTION

Soccer, which has hundreds of thousands of licensed athletes from children to adults, from women to men, has turned into a giant industry as the most popular sport in the world (Aşçı, 2009; Sarıakçalı et al., 2020; Sarıakçalı et al., 2022). The transfer value of football players increases every year and millions of dollars are spent on football. (Singh & Lamba 2019). Football clubs that have such valuable athletes limit their athletes to a very short training period during the year to prepare them before the competition, as opposed to a very long season (Okba et al., 2018). Football is a team sport played with players performing at high speed, intensity or intermittently interspersed with recreational activities (Castagna et al., 2018; Hostrup et al., 2019). Besides, football is a complex sport (Casanova et al., 2013), and players require high levels of aerobic and anaerobic fitness to compete (Reilly et al., 2000). Coaches must control the training process (exercise intensity, volume, duration, frequency, rest interval, etc.) very well in order to maximize the athletes' performance during this short preparation period. They also need to be in a state of complete well-being to perform at their highest level. Due to the nature of football, athletes have to cover long distances with high-intensity runs and sprints. Players have to move in sprints both in defense and attack. Therefore, football is a sport in which the anaerobic energy system is predominantly used (Suhadak, 2017; Erail & Uzun, 2023). For this reason, intense intermittent loading strategies performed at above-maximum intensity are used in training to maximize the performance of athletes (Mohr et al., 2003; Tonnessen et al., 2011; Laia et al., 2015).

It is stated that various HIIT protocols increase the conditioning of athletes in interval sports such as football (Wiewelhove et al., 2018), and HIIT is frequently used in modern training programs and especially in team sports such as football to improve athletes' fitness (Laia et al., 2009). HIIT protocols typically lead to high HR

[1] Uşak University, Faculty of Sports Sciences, Uşak, Türkiye

[2] Uşak University, Faculty of Sports Sciences, Uşak, Türkiye

and high blood La levels (Menzies et al., 2010). In HIIT protocols, exercise exceeds aerobic capacity and adenosine three phosphate (ATP) used for energy is met from anaerobic metabolism. As a result, there is excessive La accumulation resulting from the anaerobic breakdown of glycogen. Accumulation of La in the muscle reduces the action potential and also causes fatigue (Torres et al., 2012; DiFrancisco et al., 2022). Lactate accumulated in the muscles and blood, shifting the pH to acidosis and preventing the glycolytic enzymes from working. This weakens the chemical reaction rates in muscle cells and reduces the athlete's performance on the field (Paskalis et al., 2022). However, this transient increase in blood La may mediate the adaptation of skeletal muscle to high-intensity training (e.g., mitochondrial biogenesis) (Brooks et al., 2008). Thus, HIIT training, which is frequently used in training, positively supports the performance of football players on the field during the match. In addition, there are increases in HR caused by sympathetic and parasympathetic activity to meet the body's needs during exercises. It is important to evaluate HR, which is among the indicators of exercise intensity, during training. During training, the athlete is exposed to external loads such as exercise volume and intensity (number of sets and repetitions, distance traveled, speed, etc.) and internal loads such as physiological changes that occur with exercise (change in HR, increase in La concentration, damage to the muscle, etc.) (Chaves et al. 2018).

Examining HR and blood La levels to determine physiological responses are low-cost and practical methods frequently used by coaches (Owen, et al. 2011). These physiological responses can be affected by training load, intensity, fatigue accumulation, and imbalances between load and recovery (Buchheit, M. et al. 2013). Inadequate recovery times and methods between sets during periods of intense load may cause a decrease in physical performance (Chaves et al., 2018). For this reason, especially in the training of young players, effective recovery methods are needed between training units (Tessitore et al., 2007). Overload in response to insufficient rest intervals can cause physiological adverse effects on both the psychological and musculoskeletal systems, metabolic systems, immune and nervous systems of athletes (Reilly & Ekblom 2005), and as a result, it can leave athletes more vulnerable to injuries (Barnett, 2006). For this reason, it is extremely important to determine both the duration and rest methods effectively during rests between repetitions. One of the most important factors of physiological and psychological injuries in collision sports such as football is the inability to apply appropriate and adequate recovery techniques after training sessions (Darani et al., 2018). The intensity, volume, duration and frequency of football training places a heavy burden on biological systems and can thus compromise the performance of players in subsequent training sessions. For this reason, today's modern football coaches take care to use a fast and effective recovery strategy between training units (Tessitore et al., 2007).

Giudice et al. (2020) emphasized that the appropriate recovery technique will help blood pressure and heart rate return to normal conditions (Giudice, et al., 2020). The most commonly used recovery techniques are passive (Darani et al., 2018) or active (Simjanovic, et al. 2009; Darani et al., 2018) recovery techniques. It has been shown that the application of AR, which generally consists of aerobic type running activities, immediately after each HIIT session can be a strong metabolic stimulant in reducing La levels (Wiewelhovei, et al. 2018). Many studies have examined the effects of post-training regeneration processes and stated that AR methods are more effective than PR for reducing blood La levels (Gmada et al., 2005; Brown et al., 2014). On the other hand, there is also evidence that PR is more effective than AR on HR (Barnett, 2006). Therefore, it strengthens the hypothesis that the PAR technique may be more effective in reducing both HR and La together.

In the literature review, many studies were found on the use of active and passive recovery techniques, but the use of passive-active combination recovery (PAR) techniques was not found. For this reason, our study aimed to examine the hypothesis that the PAR technique may be more effective in decreasing both HR and La together immediately after the HIIT session applied to professional football players.

METHODS

Research Group

28 trained professional male soccer players (age: 24.79±2.75 years, height: 180.50±5.81 cm, weight: 74.18±5.47 kg) from the Türkiye Super League team participated in this study voluntarily. Before starting the research,

permission was obtained from the club management and the club doctor stating that there was no harm in athletes participating in training and tests. Participants were also informed about potential risks and discomforts associated with the study. Then, the forms prepared in accordance with the rules of the Declaration of Helsinki were signed by the players. Before the study, participants' resting heart rate (RHR) and blood La levels were taken from the lactate test. Football players were estimated at 2 millimoles/Liter (2 mM/L) for regeneration HR and 4 millimoles/Litre (4 mM/L) for anaerobic threshold HR. In order to equalize the load and rest HRs of the participants, they were assigned to 3 groups: Red, White and Blue, according to the HR and La answers that were close to each other.

Measurements and Tests

Age: Taken in years according to club license information.

Height: Their height was measured in an upright position, in shorts and bare feet, with a stadiometer with an accuracy of ±0.01 cm.

Body weight (BM) and Body Mass Index (BMI): BM and BMI values were determined by taking automatic printouts from a body composition measuring device (TanitaBC-418 MA, Japan) in shorts and bare feet.

Heart Rate (HR): Resting heart rate (RHR) and HR values during interval training were determined in beats/minute with a portable heart rate monitor (Polar S810i, Oy, Kempele, Finland).

Lactate Test: Athletes started with a 3-minute run on the treadmill at 0 degree incline and 8 km/h speed. After every 3 minutes of running, 1 km/h was gradually increased. Athletes continued testing until they were exhausted. A 30-second full passive rest period was applied after each speed level. Meanwhile, blood samples were taken from the athlete and pulse rates at the speed level were recorded.

Lactic acid concentration (La): Blood samples taken from lactate tests and after HIIT, La (mM/L) values were determined with Lactate Scout (Leipzig, Germany).

Loading Intensity (LI): LI values of each interval training were determined according to the Karvonen method (Brouwer, AM. et al. 2018).

Karvonen formula: **THR = RHB + (HRmax – RHB) x LI**

THR: Target Heart Rate; RHB: Resting Heart Rate; HRmax: Maximal Heart Rate (220 – age); LI: Loading Intensity

High-Intensity Interval Training (HIIT) Program

The HIIT program was applied in the second week of the first preparation period and for a total of 12 minutes over 1 set. The exercise was performed as 5 repetitions of 2 minutes (1 set=5x2 minutes) and 30 seconds of jogging-style active rest was given between repetitions.

Interval training is based on the principle of second load without eliminating the effect of the first load (Güllü and Güllü, 2001). Therefore, 2 minutes of loading and 30 seconds of jogging (1:1/4 ratio) were applied for the work and rest periods between HIIT repetitions. At the end of the set, a 2-minute recovery period (1:1 ratio) was applied for the work and rest periods.

Table 1: HIIT program [α]

Number of sets	Number of repetitions	Loading time	Rest interval
1	5	2 minutes	**Between repetitions: 30 seconds; End of set: 2 min.** (The groups applied 3 different recovery techniques alternately: PR, AR and PAR)
[α]*Training Frequency: 3 days/week (Monday, Wednesday, Friday)*			

Recovery Techniques Applied by Groups

Footballers assigned to Red, White and Blue groups; At the end of the HIIT programs applied on Mondays, Wednesdays and Fridays, they applied 3 different recovery techniques, namely passive recovery (PR), active recovery (AR) and passive-active combination recovery (PAR), respectively.

Table 2: Recovery techniques applied by the groups

N	Recovery Technique	Recovery Activity
1	Passive Recovery (PR)	2 minutes sitting
2	Active Recovery (AR)	2 minutes jogging at a heart rate of 2mM/L
3	Passive-Active Combination Recovery (PAR)	1 min passive *(sitting for alactacid O_2 debt)* and 1 min active *(jogging at a heart rate of 2mM/L for lactacid O_2 dept)*

Table 3: Recovery techniques applied by groups alternately according to days

Groups/Days	Monday	Wednesday	Friday
RED	PR	AR	PAR
WHITE	AR	PAR	PR
BLUE	PAR	PR	AR

HR and La values of each group were taken twice, immediately after the end of HIIT and at the end of the applied recovery techniques.

Statistical Analysis

Statistical calculations of the research were made with IBM SPSS 25.0 package program. Descriptive statistics of the data obtained were made and presented as mean and standard deviation (mean±SD) in the text. Shapiro-Wilk test was used for normality tests of all data. Since all data showed normal distribution ($p>0.05$), parametric tests were applied. Differences between groups were determined by repeated measures One-Way ANOVA test. In case of a difference between the groups, Tukey HSD multiple comparison (post-hoc) test was applied to determine which group caused the difference. $p<0.05$ level was considered significant in all tests.

RESULTS

The HR, La and LI values of the Red, White and Blue groups that applied HIIT programs on Mondays, Wednesdays and Fridays, and the data obtained from the HR and La responses of 3 different recovery techniques applied alternately were given below in tables.

Table 4: Descriptive statistics, ANOVA and post-hoc values of the research group

					95% Confidence Interval				
Variable	**Group**	**N**	**Mean**	**SD**	**Lower Limit**	**Upper Limit**	**F**	**p**	**Post-Hoc**
Age (yıl)	RED	10	26,10	1,45	25,06	27,14	2,45	0,106	
	WHITE	9	24,67	2,96	22,39	26,94			
	BLUE	9	23,44	3,21	20,98	25,91			
	Total	28	24,79	2,75	23,72	25,85			
Height (cm)	RED	10	181,50	7,85	175,89	187,12	0,26	0,776	
	WHITE	9	179,56	4,53	176,07	183,04			
	BLUE	9	180,33	4,66	176,75	183,92			
	Total	28	180,50	5,81	178,25	182,75			
Body Weight (kg)	RED	10	76,30	6,16	71,89	80,71	1,39	0,268	
	WHITE	9	73,78	4,26	70,51	77,05			
	BLUE	9	72,22	5,50	67,99	76,45			
	Total	28	74,18	5,47	72,06	76,30			
BMI (kg/m²)	RED	10	23,14	0,63	22,69	23,59	2,93	0,072	

	WHITE	9	22,87	0,59	22,42	23,32			
	BLUE	9	22,20	1,25	21,24	23,16			
	Total	28	22,75	0,93	22,39	23,11			
RHR (beats/min)	RED	10	64,30	5,23	60,56	68,04	1,85	0,179	
	WHITE	9	61,22	4,89	57,46	64,98			
	BLUE	9	60,56	3,21	58,09	63,02			
	Total	28	62,11	4,70	60,28	63,93			
HRmax (beats/min)	RED	10	193,90	1,45	192,86	194,94	2,45	0,106	
	WHITE	9	195,33	2,96	193,06	197,61			
	BLUE	9	196,56	3,21	194,09	199,02			
	Total	28	195,21	2,75	194,15	196,28			
HR at 2mM/L (beats/min)	RED	10	132,00	4,52	128,77	135,23	23,07	0,000	R<W<B
	WHITE	9	136,00	2,45	134,12	137,88			
	BLUE	9	145,33	5,50	141,11	149,56			
	Total	28	137,57	7,07	134,83	140,31			
HR at 4mM/L (beats/min)	RED	10	167,00	3,56	164,45	169,55	31,60	0,000	R<W<B
	WHITE	9	172,33	2,29	170,57	174,09			
	BLUE	9	178,56	3,43	175,92	181,19			
	Total	28	172,43	5,72	170,21	174,65			

**The mean difference is significant at the 0.05 level. SD: Standard Deviation*

Table 5: ANOVA and multiple comparison (post-hoc) statistics of the groups on Monday

Variable	Group	N	Mean	SD	F	p	Post-Hoc
HR at the end of HIIT (beats/min)	RED: **PR**	10	167,20	3,49	56,83	0,000*	PR<AR<PAR
	WHITE: **AR**	9	172,33	2,29			
	BLUE: **PAR**	9	183,89	4,31			
La at the end of HIIT (mM/L)	RED: **PR**	10	8,52	1,05	0,46	0,639	PT≤PAT≤AT
	WHITE: **AR**	9	9,18	2,03			
	BLUE: **PAR**	9	8,58	1,73			
HR at the end of recovery (beats/min)	RED: **PR**	10	6,64	0,91	6,61	0,008*	AT≤PAT<PT
	WHITE: **AR**	9	6,62	1,71			
	BLUE: **PAR**	9	5,71	1,12			
La at the end of recovery (mM/L)	RED: **PR**	10	79,39	3,40	1,58	0,226	PT≤PAT≤AT
	WHITE: **AR**	9	82,87	2,88			
	BLUE: **PAR**	9	90,74	2,95			
Loading Intensity (%)	RED: **PR**	10	79,39	3,40	32,94	0,001*	PT≤AT<PAT
	WHITE: **AR**	9	82,87	2,88			
	BLUE: **PAR**	9	90,74	2,95			

**P<0.05; SD: Standard Deviation; PR: Passive Recovery; AR: Active Recovery; PAR: Passive-Active Combination Recovery; <: Significantly in favor; ≤: Insignificantly in favor*

In the intergroup ANOVA and post-hoc comparisons of the HIIT program performed on Monday, HR and LI values at the end of HIIT were significant in favor of the PAR group, and the HR value at the end of recovery was significant in favor of the PR group ($p<0.05$).

Table 6: ANOVA and multiple comparison (post-hoc) statistics of the groups on Wednesday

Variable	Group	N	Mean	SD	F	p	Post-Hoc
HR at the end of HIIT (beats/min)	RED: **PR**	10	174,30	4,22	9,23	0,004*	AT<PAT<PT
	WHITE: **AR**	9	176,44	2,51			
	BLUE: **PAR**	9	180,67	2,65			
La at the end of HIIT (mM/L)	RED: **PR**	10	8,22	0,97	0,59	0,562	PT≤PAT≤AT
	WHITE: **AR**	9	7,81	1,26			
	BLUE: **PAR**	9	7,64	1,35			

HR at the end of recovery (beats/min)	RED: **PR**	10	122,20	4,71	14,91	0,002*	AT<PT<PAT
	WHITE: **AR**	9	108,78	5,93			
	BLUE: **PAR**	9	107,56	8,56			
La at the end of recovery (mM/L)	RED: **PR**	10	5,42	0,84	0,69	0,512	PT≤AT≤PAT
	WHITE: **AR**	9	5,11	0,68			
	BLUE: **PAR**	9	5,67	1,38			
Loading Intensity (%)	RED: **PR**	10	84,84	4,00	2,89	0,074	AT≤PAT≤PT
	WHITE: **AR**	9	85,97	3,21			
	BLUE: **PAR**	9	88,37	2,11			

**P<0.05; SD: Standard Deviation; PR: Passive Recovery; AR: Active Recovery; PAR: Passive-Active Combination Recovery; <: Significantly in favor; ≤: Insignificantly in favor*

In the intergroup ANOVA and post-hoc comparisons of the HIIT program performed on Wednesday, the RH value at the end of HIIT was significant in favor of the PT group, and the RH value at the end of recovery was significant in favor of the PAT group (p<0.05).

Table 7: ANOVA and multiple comparison (post-hoc) statistics of the groups on Friday

Variable	Group	N	Mean	SD	F	p	Post-Hoc
HR at the end of HIIT (beats/min)	RED: **PR**	10	167,20	3,49	56,83	0,000*	PT<AT<PAT
	WHITE: **AR**	9	172,33	2,29			
	BLUE: **PAR**	9	183,89	4,31			
La at the end of HIIT (mM/L)	RED: **PR**	10	8,52	1,05	0,46	0,639	PT≤PAT≤AT
	WHITE: **AR**	9	9,18	2,03			
	BLUE: **PAR**	9	8,58	1,73			
HR at the end of recovery (beats/min)	RED: **PR**	10	6,64	0,91	6,61	0,008*	AT≤PAT<PT
	WHITE: **AR**	9	6,62	1,71			
	BLUE: **PAR**	9	5,71	1,12			
La at the end of recovery (mM/L)	RED: **PR**	10	79,39	3,40	1,58	0,226	PT≤PAT≤AT
	WHITE: **AR**	9	82,87	2,88			
	BLUE: **PAR**	9	90,74	2,95			
Loading Intensity (%)	RED: **PR**	10	79,39	3,40	32,94	0,001*	PT≤AT<PAT
	WHITE: **AR**	9	82,87	2,88			
	BLUE: **PAR**	9	90,74	2,95			

**P<0.05; SD: Standard Deviation; PR: Passive Recovery; AR: Active Recovery; PAR: Passive-Active Combination Recovery; <: Significantly in favor; ≤: Insignificantly in favor*

In the intergroup ANOVA and post-hoc comparisons of the HIIT program performed on Friday, the HR and LI values at the end of HIIT were significant in favor of the PAT group, and the HR value at the end of recovery was significant in favor of the PT group (p<0.05).

No significant difference was observed in La levels between groups (p>0.05), whereas significant differences were observed between HR and LI (p<0.05). According to the results of multiple comparisons, although the improvement in La levels was in favor of AR, it was not statistically significant (p>0.05). HR values at the end of HIIT and recovery were found to be significant in favor of PAT and PT, and LI values were found to be significant in favor of the PAT group (p<0.05).

DISCUSSION

Various HIIT protocols are stated to increase the fitness of athletes in interval sports such as soccer (Wiewelhove et al. 2018). In HIIT protocols, exercise exceeds aerobic capacity and ATP used for energy comes from anaerobic metabolism. As a result, there is excessive La accumulation resulting from the anaerobic breakdown of glycogen (Torres et al., 2012; DiFrancisco et al., 2022). Regarding acute physiological responses, HIIT protocols typically lead to extremely high blood lactate levels (11.2 mM/L) (Wiewelhove, et al. 2018).

Although most studies have unanimously shown that AR allows faster return of La to resting lactate levels than PR (Barnett, (2006). Using recovery modalities between training sessions in elite athletes: does it help? Sports Med. 36, 781–796. doi: 10.2165/00007256-200636090-00005), the decreases in La levels between all three groups were not significant (p>0.05). This may explain why increases in HIIT load create a heavy burden on football players' biological systems (Tessitore et al., 2007). Additionally, adaptations such as increases in skeletal muscle oxidative capacity and lipid oxidation within a given recovery period in all three techniques may suggest that La decreases to similar levels (Wiewelhove, et al. 2018).

On the other hand, the HR and interval intensity values at the end of HIIT were significant in favor of the PAT group, and the HR value at the end of the recovery was significant in favor of the PT group ($p<0.05$; Table 6). For this reason, HIIT increases the heart rate and breathing rate and provides increased blood flow to the working muscle groups, while it may also increase the blood pressure in the blood vessels (Israel, 1993). Therefore, the chronic effect of training causes a decrease in heart rate and an increase in heart stroke volume (Güllü & Güllü 2001), it may have triggered significant improvements in the HR values of the PAR and PR groups.

Although the percentage of LI was in favor of PAR (Table 7), the decrease in both HR and La together was significant in favor of the PAR group compared to the other two recovery techniques ($p<0.05$; Table 6). However, AR was more effective in decreasing La levels, and PR was more effective in decreasing HR. The reason for this can be said that proper recovery technique helps blood pressure and heart rate return to normal conditions (Giudice et al., 2020). Additionally, it can be said that the adaptation of skeletal muscle to HIIT was mediated by mitochondrial biogenesis (Brooks, et al. 2008). Accordingly, this may explain why the PAR technique is more effective in reducing both HR and La together. However, the decreases in La levels between all three groups were not significant ($p>0.05$). It is stated that high-intensity training sessions such as HIIT increase the fitness of football players in intermittent sports such as football (Wiewelhove, et al. 2018). Thus, since the oxidative and lipid oxidation capacities of skeletal muscles increased, La levels may have decreased within the recovery period given in all three recovery techniques.

CONCLUSION

In the second week of the first preparation period, HIIT programs were applied to professional football players on 3 different days. When the passive, active and passive-active combination recovery techniques applied alternately after HIIT were examined, the following results were obtained.

Passive recovery technique and passive-active combination recovery technique were effective in reducing HR level. Active recovery technique and passive-active combination recovery technique were effective in reducing the La level. Therefore, it can be said that the passive-active combination recovery technique is more effective in reducing both HR and La levels together. As a result, it may be recommended that soccer coaches apply the passive-active combination recovery technique, especially in high-intensity interval training.

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