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ORIGINAL ARTICLE

Impact of Linear vs. Change-of-Direction HIIT on Aerobic Power in Female Football Players

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ABSTRACT

Background. Coaches predominantly utilize linear training protocols to enhance the aerobic power of football players. However, there is limited data on the effects of change of direction (COD) protocols on aerobic power in football. **Objectives.** This study aimed to determine which high-intensity interval training (HIIT) program—linear (LHIIT) or change of direction (COD)—has a more significant impact on increasing aerobic power in senior female football players. **Methods.** Sixty senior female football players were divided into two experimental groups: LHIIT (n=30) and COD (n=30). Both groups underwent a four-week HIIT protocol, with LHIIT involving linear and COD incorporating change-of-direction exercises. Aerobic power was measured using the 30-15 intermittent fitness test (IFT), maximal aerobic velocity (MAV), and VO_2max at the beginning and end of the study to assess the differences in aerobic adaptations between the two programs. **Results.** The results indicated that the COD group eliminated the significant difference in VO_2max that initially existed between the two groups, suggesting that COD protocols may be more effective in increasing aerobic power than linear ones. Additionally, both groups significantly improved the 30-15 IFT, MAV, and VO_2max. **Conclusion.** Both linear and change-of-direction HIIT protocols significantly enhance aerobic performance in senior female football players. However, COD protocols may have a more significant impact on VO_2max improvement. Future research should explore the potential effects of COD protocols on anaerobic power and seek to identify even more effective HIIT strategies for enhancing VO_2max.

INTRODUCTION

Aerobic capabilities appear to be a significant factor in overall football performance. Lower maximal aerobic capacity is associated with increased fatigue and declines in both physical performance and technical skills during match play in football (1). Conversely, higher VO_2max values have been associated with improved running performance, including higher work rate

and intensity, and increased sprints during match play (2-5). Thus, sprints frequently involve various high-intensity interval training (HIIT) programs.

HIIT (High-Intensity Interval Training) is a training method in which periods of high and low intensity or rest alternate. It is considered one of the most effective methods to improve the cardiorespiratory and metabolic systems because it encompasses short, high-intensity intervals with resting or low-intensity phases. This type of training develops strength and endurance, stimulates testosterone secretion, and increases muscle strength (6).

Many HIIT programs are applied in training, and different forms of HIIT exist, considering athletes' specific goals. In football, however, coaches usually use the linear HIIT protocols. Structurally, speaking of whole-body movement in football, there are two main movement patterns- linear and variable situation-dependent direction changes. Indeed, knowing the nature of a football game, HIIT training changes its direction, which appears to be more specific to football performance, as most activities in the football game are taken in off-the-ball conditions (1). Acceleration ability, muscular strength, and body makeup were predictors of change of direction (COD) ability in the population of elite-level soccer players (7). HIIT training with a change of direction is considered an essential component of ability development because it adapts to the demands of the game due to the alternation of low and high intensity (8). The analysis showed that combining HIIT and COD training improves aerobic and anaerobic capabilities by creating a higher physiological load (9). When changing the direction of movement, it is mandatory to reduce the distance at which the run is due to the loss of time during the turn, so that the load is similar to running without turns (10). Previous studies have analyzed the effects of HIIT on football players' aerobic, anaerobic, and motor abilities (11-15).

Studies on female soccer players proved that strength training increases aerobic and anaerobic power (16). Thus, aerobic fitness measures were significantly related to linear sprint over 0–40m & 20–40m sprint times, repeated sprint ability (RSA) fastest time, total time, mean time, and change of direction sprint in female football players (17). Furthermore, a recent review (18) concluded that HIIT significantly affects VO_2max, RSA, change of direction speed, speed, and explosive strength in female team sports, regardless of the competition level. There is still no evidence about the possible differences in the linear and COD HIIT training effects on the aerobic power of senior female football players.

Therefore, this research aims to determine which HIIT training program most effectively affects the aerobic power increase in senior female football players.

MATERIALS AND METHODS

Ethics Committee approval. This study was approved by the Ethics Committee of the Faculty of Kinesiology, University of Zagreb, and was carried out following the Helsinki Declaration. All examinees signed a statement expressing their willingness to proceed with all the testing for this research.

Participants. The participants comprised 60 senior female football players, randomly separated into two experimental groups, LHIIT (n=30) and COD (n=30). All participants are adults, and written consent was obtained before any experimental work was performed.

Procedure. Initially, anthropometric measurements were taken to understand the subjects better. Body height was measured with the Harpander Anthropometer in the "Frankfurt horizontal" position. The TANITA diagnostic scale (BC-760) assessed body weight and body fat.

Aerobic power as the primary matter of interest was measured through the 30-15IFT (19), while after that, VO_2max was estimated using equations proposed by Andersen et al. (20) through the 30-15IFT results of every individual.

Two experimental groups were engaged in specific training programs for four weeks, two times per week, on Tuesdays and Thursdays. Training programs were applied following their football coaches and coaching teams. Testing was carried out at the Faculty of Kinesiology in Zagreb of the Diagnostic Center, and on the football fields of ŽNK Split – Split, ŽNK Osijek – Osijek, and NK Neretva-Metković. The subjects started with their dominant leg from a semi-high or medium start, while the group that did the turn alternated with the dominant leg and then the weaker leg. Larus Sport, a company specializing in sports diagnostics, fitness, medicine, and rehabilitation, conducted an extensive measurement using mobile spiroergometry. This detailed assessment was

carried out by a team of experienced assessors from the diagnostic organization, who received valuable assistance and collaboration from the coaches at the club. Their combined efforts ensured the accuracy and thoroughness of the data collected, contributing significantly to the overall success of the measurement process. In the first phase, subjects were tested through the 30-15IFT, and maximal aerobic velocity (MAV) (21), as well as the VO_2max determination (10), were estimated after adapting the following training programs accordingly. The training program involved 15x15 sec HIIT training in 100% MAV in four series with eight repetitions for the first two weeks. The second two-week program was adapted as the repetition number was raised to ten. In the final phase, subjects were tested again to detect possible differences in the effects of linear and change-of-direction HIIT training programs.

Data analysis. The obtained data was analyzed using Statistica 14.0. Initial results within the groups were tested for normality of distribution to ensure an equal initial stance. However, the first (control) group had slightly higher initial VO_2max and Body fat. The first phase included descriptive statistics of the total sample. The Student t-test was applied with a significance level of $p<0.05$ to determine the possible differences in aerobic power between the groups. Data is available through personal communication with the authors.

RESULTS

Descriptive data were extracted to gain insight into the sample's anthropometric and functional characteristics. The results are visible in Table 1.

As presented in Table 1, LHIIT and COD groups are relatively homogenous, except in the variables of Body fat and VO_2max, where the first group had slightly greater results. The LHIIT group had slightly better results in all variables and was a bit higher and heavier on average than the COD group.

Table 1. Descriptive statistics for the total sample (n=60) of female senior football players, separated by groups of importance.

Groups	LHIIT (n=30)		COD (n=30)	
	Mean	SD	Mean	SD
30-15IFT 1 (km/h)	19.42	1.61	19.16	1.14
VO_2max 1 (ml/kg/min)	52.64*	2.39	51.19	3.12
MAV 1 (km/h)	16.94	0.83	16.70	0.90
Weight (kg)	61.13	7.57	58.34	5.40
Height (cm)	169.21	7.79	166.68	6.80
Body fat (%)	15.81*	3.42	13.46	3.29

SD: standard deviation; *: significantly greater value ($p<0.05$); LHIIT: linear HIIT group; COD: change of direction HIIT group; 30-15IFT 1: initial results of 30-15 intermittent fitness test; VO_2max 1: initial results of maximum oxygen uptake; MAV 1: initial maximal aerobic velocity.

Interesting results of the longitudinal analysis are presented in Table 2. After the specific training programs were applied, the LHIIT group had greater improvements in 30-15IFT and MAV, but COD somehow had greater improvements in VO_2max. Therefore, change of direction training drills seem more successful in VO_2max enhancement than linear drills. Linear drills still appear reasonable for the 30-15IFT performance and maximal aerobic velocity, in contrast to the change of direction programs.

Table 2. Differences between the initial and final measurements in both groups.

Groups	LHIIT				COD			
	Mean	SD	t	p	Mean	SD	t	p
30-15IFT 1	19.35	1.59	-9.545	0.000	19.16	1.14	-5.426	0.000
30-15IFT 2	20.54	1.60			19.90	1.32		
VO_2max 1	52.64	2.39	-3.532	0.001	51.19	3.12	-8.804	0.000
VO_2max 2	53.38	2.75			52.11	2.87		
MAV 1	16.94	0.83	-6.403	0.000	16.70	0.90	-6.340	0.000
MAV 2	17.44	0.83			17.10	0.86		

t: t-test value; p: significance level; SD: standard deviation; 30-15IFT 1: initial results of 30-15 intermittent fitness test; VO_2max 1: initial results of maximum oxygen uptake; MAV 1: initial maximal aerobic velocity; 30-15IFT 2: final results of 30-15 intermittent fitness test; VO_2max 2: final results of maximum oxygen uptake; MAV 2: final maximal aerobic velocity.

Looking at the results in Table 3 and the absence of differences between results in both groups, it seems that both training programs successfully enhance the performance in 30-15IFT, maximum oxygen uptake, and aerobic velocity. However, the final absence of differences between the groups in VO_2max is significant information. Indeed, the LHIIT group initially had significantly greater VO_2max (Table 1), but the COD group managed to reduce the difference to a non-significant level. Therefore, COD has made better improvements in VO2max due to the application of a specific change-of-direction training program.

Table 3. Differences in the final results between the selected groups.

Variables	Mean 1	Mean 2	SD 1	SD 2	t	p
30-15IFT 2	20.54	19.90	1.60	1.32	1.668	0.101
VO_2max 2	53.38	52.11	2.75	2.87	1.743	0.087
MAV 2	17.44	17.10	0.83	0.86	1.577	0.120

Mean 1: final results of Group 1; Mean 2: final results of Group 2; SD 1: standard deviation of the Group 1 results; SD 2: standard deviation of the Group 2 results; 30-15IFT 2: final results of 30-15 intermittent fitness test; VO_2max 2: final results of maximum oxygen uptake; MAV 2: final maximal aerobic velocity; t: t-test value; p: significance level.

DISCUSSION

The Intermittent Fitness Test (30-15IFT) has become popular lately in football as the field test for cardiorespiratory fitness estimations. However, even though it was not developed for that particular purpose, the 30-15IFT is still often used to estimate the VO_2max (22). Although such estimations are not clinically accurate, their practical applicability ensured relatively high usability in football clubs. Therefore, VO_2max estimations through this method and comparable data have significant value in practice. However, differences obtained within the participating groups suggest that the COD HIIT training protocols stimulate aerobic power more than the linear HIIT protocols. This agrees with the previous findings (23), where the groups with more CODs had greater improvements, while in one case, the groups' results were similar (24). Speaking of improvement, it is already known that HIIT offers significant benefits for improving aerobic endurance (25), as well as the aerobic performance of players over a short period (26-28).

Anaerobic and aerobic capacity are vital areas in modern football. Improving these physiological parameters can potentially improve results in laboratory and field tests and plays a crucial role in real-world competitive situations (Martinez-Lagunas et al. 2014). Studies that support these findings often point out that training that simulates the specific demands of the sport (such as changes of direction) is more effective in improving athletic performance than general fitness training. In addition, research has shown that HIIT training can significantly impact various aspects of an athlete's physical preparation, including an increase in VO_2max, anaerobic capacity, speed, agility, and overall improvement in endurance (25, 29, 30).

Our findings indicate that high-intensity interval training (HIIT) programs incorporating direction changes are more effective in developing various physical abilities in female soccer players than traditional linear HIIT programs. These results have significant practical implications for coaches and fitness professionals aiming to optimize training to enhance performance and minimize injury risk in female soccer players. The study highlights and confirms the superior impact of COD HIIT on VO_2max and aerobic power compared to linear HIIT protocols.

CONCLUSION

This research focuses on aerobic power improvements among senior female football players. Invited by the previous findings, which proved the positive impact of HIIT, the authors tried to define which HIIT structure may be the most appropriate for aerobic power improvement in female seniors. Change of direction requires additional energy expenditure and is more stressful for the organism. Consequently, COD HIIT causes more remarkable cardiorespiratory fitness adaptation and aerobic power. Limitations of this study occur in the indirect estimations of VO_2max, which were intentionally estimated accordingly because of greater data applicability in practice. Future investigations should check the anaerobic power changes regarding these different HIIT protocols and between different age and sex groups within football or between similar team sports.

APPLICABLE REMARKS

- The conducted research complements the literature and provides a scientific, theoretical, and practical insight into women's football, addressing a gap compared to the extensive research on male players.
- HIIT training with a turn is better than HIIT training without turns in terms of aerobic power. In this way, new scientific knowledge will be obtained.
- The study provides relevant information about two types of training that will be carried out without combining them with any other training, providing a clear picture of the concrete effects of these pieces of training.

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AUTHORS' CONTRIBUTIONS

Study concept and design: Besnik Morina, Matej Babić, Goran Sporiš. Acquisition of data: Davorin Antonić. Analysis and interpretation of data: Ivica Franjko, Zvonimir Tomac. Drafting the manuscript: Grgur Višić, Goran Sporiš, Miljenko Franić. Critical revision of the manuscript for important intellectual content: Onur Akman, Miljenko Franić, Tomislav Vlahović. Statistical analysis: Ivica Franjko, Zvonimir Tomac. Administrative, technical, and material support: Besnik Morina. Study supervision: Besnik Morina, Goran Sporiš.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

FINANCIAL DISCLOSURE

There are no financial conflicts of interest to disclose.

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This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

ETHICAL CONSIDERATION

This study was approved by the Ethics Committee of the Faculty of Kinesiology, University of Zagreb, and was carried out following the Helsinki Declaration. All examinees signed a statement expressing their willingness to proceed with all the testing for this research. To protect participant confidentiality, all data were anonymized and stored securely. We ensured that participants were free to withdraw from the study at any time without any repercussions.

ROLE OF THE SPONSOR

There were no sponsors for this research. The study was conducted independently, without any external funding or influence.

ARTIFICIAL INTELLIGENCE (AI) USE

Artificial intelligence was not used in this research.

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