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ORIGINAL ARTICLE

The Revelation of Linear and Change of Direction HIIT Training Effects on the Anaerobic Power of Female Football Players

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ABSTRACT

Background. Anaerobic and aerobic power are critical factors influencing peak football performance. This study aimed to explore the differential effects of various high-intensity interval training (HIIT) protocols on these performance metrics in senior female football players. **Objectives.** The primary objective was to investigate the impact of linear (L) HIIT and change-of-direction (COD) HIIT protocols on key performance indicators, including peak treadmill running velocity (Vmax), peak velocity at anaerobic threshold (V_{AT}), distance traveled in the anaerobic zone (d_{AT}), and VO_2max. **Methods.** Sixty senior female football players were divided into LHIIT (n=30) and COD (n=30). Both groups underwent initial testing before participating in their respective training programs for four weeks. Performance metrics were measured at the beginning and end of the training period. **Results.** Both groups significantly improved all measured variables ($p<0.001$). However, the COD group demonstrated relatively more significant enhancements in Vmax (COD=0.93; LHIIT=0.8), V_{AT} (COD=0.94; LHIIT=0.87), and VO_2max (COD=0.92; LHIIT=0.74). The COD group also reduced the initial difference in VO_2max to a non-significant level. **Conclusion.** COD HIIT protocols appear to be slightly more effective in enhancing anaerobic power in female football players than linear HIIT protocols. Nevertheless, both HIIT programs significantly improved performance metrics, indicating that incorporating such training regimens can benefit female football training programs.

INTRODUCTION

Earlier findings (1, 2) suggest that high-intensity interval training (HIIT) significantly affects the anaerobic ability increase. These positive adaptations may include increased anaerobic enzyme activity, increased force production, increased intramuscular glycogen, or shifts within major fibre-type groups. Neural adaptations may include improved motor unit recruitment and synchronization, improved force development rate, and improvements in the stretch-shortening cycle (3). According to a recent review, HIIT programs, regardless of the

type, induce improvements in VO_2max, RSA, change of direction speed, speed, explosive strength of the lower limbs, and body composition in female athletes engaged in team sports (4).

Football players have many time-limited tasks throughout the game, where the success of almost every specific movement, to a certain extent, depends on the quickness ratio between the player and the opponent. Such quick actions certainly (besides the aerobic background) engage mainly anaerobic power. Therefore, anaerobic capacity is one of the main determinants of overall football performance. The velocity at the anaerobic threshold (V_{AT}), at the respiratory compensation point (VRCP), and its maximum (Vmax) play an essential position in the endurance performance assessment, both for professional and recreational endurance athletes (5), as peak treadmill running velocity is at least as good a predictor of running performance as the lactate analysis (6).

Many different (and similar) HIIT protocols are constructed for improvement in various activities and tasks. HIIT protocols are frequently applied in football training, but their efficacy in improvement varies. So far, short-duration HIIT has proven (7) to improve VO_2max in female senior football players. Significant improvements (up to 10%) were also reported after the skill-based HIIT training protocol (8) in female futsal players. Further, one study compared the effects of two different HIIT programs- heart rate-based HIIT and speed-based HIIT in female football players. Both programs induced meaningful improvements in power, VO_2max, and fatigue index, although the speed-based HIIT group achieved more significant gains in power (9). However, no experimental findings involve the linear or change of direction of HIIT programs and their impact on anaerobic power.

This study, therefore, aims to determine the effects that two different HIIT programs, a) linear and b) change of direction, have on the anaerobic power in senior female football players. The second goal is to determine the difference in the benefits between these two protocols.

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 sample of the analyzed athletes consisted of n=60 senior female football players, randomly segregated into two groups: 1) linear high-intensity interval training (control) group (LHIIT) (n=30), and 2) change of direction high-intensity interval training (experimental) group (COD) (n=30).

Procedure. Anthropometric measurements and aerobic capacity testing were initially applied to gain a clear anthropological picture of the subjects. 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 capacity levels were estimated using 30-15 intermittent fitness tests (IFT)- maximal aerobic velocity and VO_2max were derived.

Anaerobic power parameters were the main goal to investigate, and the authors assessed it using the treadmill (Rodby™, RL 1600E, Enhorna, Sweden) through the Treadmill anaerobic test protocol (10). Variables of importance were the peak treadmill running velocity (Vmax), peak velocity at anaerobic threshold (V_{AT}), distance traveled in the anaerobic zone (d_{AT}), and VO_2max. VO_2max values were estimated using the Bruce protocol (11).

Two experimental groups were engaged in specific training programs for four weeks, two times per week, on Tuesdays and Thursdays. Training programs were applied under 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 between the dominant and weaker legs. 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 anthropometric

measurements and 30-15IFT, while the maximal aerobic velocity (MAV) (12), as well as the VO_2max (13), were estimated a priori to adapt the following training programs. The main data were the anaerobic parameters, measured initially and after the adapted program. Anthropometric and anaerobic power measurements were undertaken in the Laboratory of Applied Kinesiology, Faculty of Kinesiology, University of Zagreb, Croatia, EU. Only professional anthropologists, kinesiologists, and PhDs were engaged in the measurement and data analysis.

The training program afterward 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 on the anaerobic power of selected subjects.

Data analysis. The obtained data was analyzed using Statistica 14.0. The first phase included descriptive statistics for the total sample. To determine the possible differences in anaerobic power between the groups, a Student t-test was applied with a significance level set to $p<0.05$.

RESULTS

Descriptive parameters helped researchers to precisely choose the right load within a HIIT training program for each group. Data is presented below in Table 1.

Table 1. Descriptive characteristics of analyzed subjects within selected groups, anthropometric and initial functional data.

Groups	LHIIT (n=30)		COD (n=30)	
	Mean	SD	Mean	SD
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
VO_2max 1 (ml/kg/min)	52.64*	2.39	51.19	3.12
V_{max} 1 (km/h)	13.77	1.65	13.50	2.24
V_{AT} 1 (km/h)	15.53	1.66	15.53	2.22
d_{AT} 1 (m)	1810.00	99.48	1746.67	183.33

*: significant value; SD: standard deviation; 1: initial measuring; V_{AT}: peak velocity at anaerobic threshold; d_{AT}: distance traveled in the anaerobic zone.

Results from Table 1 reveal the slight initial difference in Body fat and VO_2max. However, the sample was relatively equal in all the other listed initial variables. V_{AT} values in both groups were the same, while the LHIIT had slightly better results in Vmax and d_{AT}. It can be said that the LHIIT group had a certain, practically perhaps non-significant advantage. Longitudinal analysis, as shown in Table 2, revealed the strong positive impact of featured programs on all followed variables. The COD group appears to be more successful in relative progress. The COD group had more remarkable progress in Vmax (0.93 compared to 0.8 in LHIIT), V_{AT} (COD - 0.94; LHIIT - 0.87), and VO_2max (COD - 0.92; LHIIT - 0.74). On the other hand, the LHIIT group had greater improvements in d_{AT}, 100m (compared to 90m in COD).

Table 2. Differences between the initial and final measurements are separated by group.

Groups	LHIIT (n=30)				COD (n=30)			
	Mean	SD	t	p	Mean	SD	t	p
V_{max} 1 (km/h)	13.77	1.65	-10.770	0.000	13.50	2.24	-20.149	0.000
V_{max} 2 (km/h)	14.57	1.70			14.43	2.22		
V_{AT} 1 (km/h)	15.53	1.66	-9.355	0.000	15.53	2.22	-11.366	0.000
V_{AT} 2 (km/h)	16.40	1.69			16.47	2.21		
d_{AT} 1 (m)	1810.00	99.48	-12.042	0.000	1746.67	183.33	-6.924	0.000
d_{AT} 2 (m)	1910.00	102.89			1836.67	175.15		
VO_2max 1 (ml/kg/min)	52.64	2.39	-3.532	0.001	51.19	3.12	-8.804	0.000
VO_2max 2 (ml/kg/min)	53.38	2.75			52.11	2.87		

t: t-test value; p: significance level; 1: initial measuring; 2: final measuring; SD: standard deviation; V_{AT}: peak velocity at anaerobic threshold; d_{AT}: distance traveled in the anaerobic zone.

The final comparison of the effects of the selected training program, as presented in Table 3, did not show any significant difference between the final results of the groups. Interestingly, the initial VO_2max difference between the groups was reduced, while the ratio among other variables remained the same. The absence of significant differences tells that both HIIT programs are suitable for enhancing anaerobic power, with slight, non-significant differences regarding their impact.

Table 3. Differences between the final results of the groups after the training programs.

	Mean 1	Mean 2	SD 1	SD 2	t	p
V_{max} 2 (km/h)	14.57	14.43	1.70	2.22	0.261	0.795
V_{AT} 2 (km/h)	16.40	16.47	1.69	2.21	-0.131	0.896
d_{AT} 2 (m)	1910.00	1836.67	102.89	175.15	1.977	0.053
VO_2max 2 (ml/kg/min)	53.38	52.11	2.75	2.87	1.743	0.087

SD: standard deviation; V_{AT}: peak velocity at anaerobic threshold; d_{AT}: distance traveled in the anaerobic zone; 1: LHIIT group; 2: COD group; t: t-test value; p: significance level.

DISCUSSION

Football is becoming more and more demanding as time passes, as its popularity and quality continuously rise. Indeed, sprinting, jumping, and COD abilities play a significant role in this sport and are directly associated with power determinants of performance (14, 15). COD drills (besides the linear) seemed appropriate and maybe even crucial for progress in final football performance, as they demand more energy through the glycolytic metabolism, which causes the adaptations- improvements in the anaerobic system.

The factors, like an increase in resting muscle glycogen content (16), neural adaptations (17), improved activities of oxidative and glycolytic enzymes (18), and so on, after HIIT ameliorate the anaerobic exercise capacity (19). As proven before, HIIT programs, such as short-duration, heart rate-based, speed-based, and skill-based programs, improve anaerobic power in female football players. Unfortunately, there were no earlier studies regarding linear and COD HIIT programs applied to female football players, so the presented data is exclusive.

As seen in Table 2, both programs successfully enhanced Vmax, V_{AT}, d_{AT}, and VO_2max, e.g., anaerobic power in selected subjects. The authors succeeded in predicting the effect of COD programs, as the relative progress was higher in the COD group for Vmax, V_{AT}, and VO_2max. The COD group regarding LHIIT managed to erase the significance of the difference in VO_2max after the program, while the differences in other variables remained non-significant.

One of the critical aspects of anaerobic fitness in soccer is the ability to recover quickly between intense efforts, which allows players to maintain a high intensity of play. HIIT training has shown effectiveness in improving this ability, increasing phosphocreatine capacity and ATP resynthesis rate, which are critical factors for anaerobic endurance (20). In addition, HIIT directional change workouts improve the biomechanical aspects of movement, reducing the risk of injury associated with high-intensity movements and sudden changes in direction (21). Also, such training can increase mental understanding and the ability to make quick decisions on the field, which is of great importance in the dynamic environment of a football match (22).

The study results show slight differences in body fat and VO_2max between the groups, with other relatively similar baseline variables. Specifically, V_{AT} was the same in both groups, but the LHIIT group performed better in Vmax and d_{AT}, resulting in a slight, almost negligible advantage for that group. During the longitudinal analysis, both programs substantially positively impacted all performance measures. The CCP group made more relative progress in Vmax (0.93 vs 0.8 in LHIIT), V_{AT} (COD - 0.94; LHIIT - 0.87), and VO_2max (COD - 0.92; LHIIT - 0.74). On the other hand, the LHIIT group saw greater improvements in d_{AT}, with an increase of 100 meters compared to 90 meters in COD. The final comparison of the effects of the training programs did not reveal significant differences between the final results of the groups. Even though the initial difference in VO_2max between the groups decreased significantly, the ratio between the other variables remained approximately the same.

Therefore, all the HIIT programs investigated appear suitable for anaerobic power enhancements

in female football players, while speed-based and COD programs may be the most successful. This is especially important for the development of female players who strive for peak performance, allowing them to better cope with the physical demands of modern football and provide optimal performances throughout the match.

CONCLUSION

To conclude, there were no significant differences between the linear and COD HIIT protocols regarding anaerobic power enhancement- variables Vmax, V_{AT}, d_{AT}, and VO_2max. Still, the COD group had greater relative improvements in Vmax, V_{AT}, and VO_2max, which means that COD drills may cause greater effects in anaerobic power regarding selected samples. HIIT programs are indeed helpful "assistants" in conditioning female senior football players. Future studies should explore the effects of other HIIT programs on the anaerobic power of female football players and find which HIIT programs in football training have the greatest transfer on which position, age, and sex.

APPLICABLE REMARKS

- The conducted research enriches the existing literature by offering scientific, theoretical, and practical insights specifically tailored to women's football.
- HIIT training with directional changes has similar effects on anaerobic power as HIIT training without directional changes, establishing both as valuable training methods.
- The findings provide clear and relevant information about the distinct impacts of these two training types, conducted independently of other training methods.
- Given their proven effectiveness, coaches and sports scientists can integrate these HIIT protocols to enhance athlete performance.
- The study also addresses a previously limited area of research on high-intensity interval training, particularly with directional changes, which has only been sporadically mentioned in prior studies.

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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, Aleksandar Miletić. Critical revision of the manuscript for important intellectual content: Onur Akman, Aleksandar Miletić, Rrezon Krasniqi. 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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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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