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ORIGINAL ARTICLE

The Effects of Linear and Change of Direction HIIT on Motor Abilities in Female Football Players

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ABSTRACT

Background. In football, both anaerobic and aerobic power are critical for optimal performance. This study aimed to compare the effects of linear and change of direction (COD) high-intensity interval training (HIIT) programs on motor performance in elite senior female football players. **Objectives.** The objective was to investigate the differential impact of linear HIIT (LHIIT) and COD HIIT protocols on various motor performance metrics, enabling coaches and athletes to optimize training strategies based on specific performance goals. **Methods.** The study involved 60 elite senior female football players, divided into LHIIT (n=30) and COD (n=30). Participants underwent pre-testing to assess their initial fitness levels, followed by a four-week HIIT training program. Performance was measured across multiple variables before and after the intervention. **Results.** The LHIIT group significantly improved eight of nine variables, demonstrating notable enhancements in sprinting, agility, and specific plyometric abilities. The COD group significantly improved six variables, excelling in agility and velocity-related tests. However, the COD group experienced an unexpected decline in the S5m variable by 0.1. **Conclusion.** Both linear HIIT and COD HIIT programs effectively enhance physical abilities in elite female football players, with each type of training showing specific strengths. Linear HIIT is more effective for improving sprint, agility, and plyometric abilities, whereas COD HIIT excels in agility and velocity-related performance. Coaches and athletes should select the HIIT protocol that best aligns with their specific performance needs and goals to optimize athletic performance in team sports.

INTRODUCTION

In team sports such as soccer, a key factor for success is applying high-intensity actions, such as accelerations, decelerations, jumps, and rapid changes in the direction of movement during the competition (1). Football players are expected to have developed aerobic and anaerobic endurance, combined with agility, to maintain a high level of performance during the game (2). Such

performance consists of many specific high-intensity activities. Most high-intensity activities occur during critical moments when competing for the ball, offensive and defensive actions, and the opportunity to score (3). As the league and age increased, high-level demands became more intensive and frequent. Female football players must spend a certain period in high-intensity zones to create an optimal stimulus, which implies working in zones of 90-95% maximum oxygen intake or maximum heart rate (4).

Given its training characteristics, high-intensity interval training (HIIT) creates appropriate high-intensity stimuli, which is very close to the requirements of games such as football, handball, and basketball (5). Football often involves many changes in the game tempo. At the same time, players use short, low-intensity activities such as standing and slow-walking to quickly recuperate for the following high-intensity activities, just like in HIIT. Some authors believe that HIIT is an important component for optimal the progression of the development of female football players, whose sports require a combination of long-term endurance and high-intensity speed (6). HIIT training with a change in the direction of movement is considered an essential component of ability development because it adapts to the demands of the game due to the change of low and high intensity (7).

In team sports such as football, success depends heavily on performing high-intensity activities such as accelerating, decelerating, jumping, and rapid changes of direction (8). Therefore, female soccer players need to optimally develop their fitness abilities, harmonizing aerobic and anaerobic endurance and agility (9). Analyses show that the combination of HIIT and COD improves aerobic and anaerobic capabilities due to the higher physiological load (10). When changing direction, it is necessary to shorten the running distance so that the load is similar to running without turns (11).

Previous research has analyzed the effects of HIIT on soccer players' aerobic, anaerobic, and motor skills (12-17). At the same time, there are no studies regarding the change of direction of HIIT in the motor abilities of senior female football players.

Therefore, the main goal of this investigation is to determine the effects of two different HIIT programs on the motor abilities of 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 under the Helsinki Declaration. All examinees signed a statement expressing their willingness to proceed with all the testing for this research.

Participants. The analyzed subjects for this research were n=60 senior female football players, randomly separated 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). All participants were adults when the research occurred, and written consent was provided a priori to any experimental work.

Procedure. Anthropometric and aerobic capacity testing were initially applied to gain a clear anthropologic picture of the selected athletes. Body height was measured with Martin Anthropometer in the "Frankfurt horizontal" position. Further, the TANITA diagnostic scale (BC-760) estimated body weight and body fat. Aerobic capacity levels were estimated using a 30-15 intermittent fitness test (IFT)- while the maximal aerobic velocity and VO_2max were derived after that.

Motor abilities to track were chosen according to the football performance demands, primarily agility, explosive power, and running velocity. The running velocity was measured with the photocells (Witty, Microgate, Italy) through the executions of sprints on the 5th, 10th, and 20th meters (S5m; S10m; S20m). The latent dimension of agility was estimated through the Test 9-3-6-3-9 (93639) (18), Agility test 505 (505) (19), and 20-yard agility test (20-yard) (20). Photoelectric cells (Witty photocell, Microgate, Bolzano, Italy) were used to detect the explosive power through the jumps. Three different jumps were performed: 1) Counter-movement jump (CMJ), 2) Squat-jump (SJ), and 3) Free jump (FJ) (21).

Two experimental groups were engaged in specific HIIT programs for four weeks, two times per week, on Tuesdays and Thursdays. Training programs were performed under the authority of their football coaches and coach 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 in the group that did the turn was alternating 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. 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 anthropometric measurements and 30-15IFT. At the same time, the maximal aerobic velocity (MAV) (22), as well as the VO_2max (23), were estimated a priori to adapt the following training programs. The primary data consisted of the motor abilities measured initially and after the adapted program. Both anthropometric and motor ability measurements were performed in the Laboratory of Applied Kinesiology, Faculty of Kinesiology, University in Zagreb, Croatia, EU. Only professional anthropologists, kinesiologists, and PhDs were engaged in the measurement and data analysis.

After the initial testing phase, 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 towards the anaerobic power of selected subjects.

Data analysis. Obtained data was analyzed using Statistica 14.0. The first phase included descriptive statistics estimation of the total sample. Student t-tests were applied to determine the possible final differences in motor abilities between the groups. Data is available through personal communication with the authors.

RESULTS

Initial testing was conducted, and descriptive data was analyzed, as shown below in Table 1.

Table 1. The descriptive characteristics of the participants were separated into groups.

Groups	LHIIT (n=30)		COD (n=30)	
	Mean	**SD**	**Mean**	**SD**
Height (cm)	61.13	7.57	58.34	5.40
Weight (kg)	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
93639 1 (s)	8.23*	0.28	7.99	0.24
505 1 (s)	2.70	0.14	2.69	0.13
20-yard 1 (s)	4.71	0.21	4.80	0.16
CMJ 1 (cm)	43.80	0.25	43.76	0.20
FJ 1 (cm)	41.70	0.33	41.87	0.37
SJ 1 (cm)	40.54	0.24	40.62	0.33
S5m 1 (s)	1.46	0.23	1.38	0.19
S10m 1 (s)	2.40	0.23	2.35	0.21
S20m 1 (s)	3.75	0.31	3.77	0.30

SD: standard deviation; 1: initial measurement; VO_2max: maximum oxygen uptake; 93639: 9-3-6-3-9 test; 505: agility test 505; 20-yard: 20-yard agility assessment test; CMJ: counter-movement jump; FJ: free jump; SJ: squat jump; S5M: 5 meter sprint; S10m: 10m sprint; S20m: 20m sprint; *: significant value.

Observed groups appear to be relatively similar in analyzed variables, as no significant difference was found between the mean results in most variables. Still, the LHIIT group had greater initial results in body fat, VO_2max 1, and 93639 1. This means that the COD group has better initial agility in this test, while the LHIIT group has bigger bodies, which results in greater VO_2max and body fat. However, it can be said that the groups were relatively correctly distributed. Somehow, the LHIIT group improved the results in eight of nine variables (except CMJ), while the COD group showed significant improvements in six variables. It seems that linear HIIT programs improve sprint,

agility, and specific plyometric abilities; COD programs initiated an improvement in 505, 20-yard, CMJ, SJ, S10m, and S20m tests. There is also a 0.1 growth in the S5m variable regarding the COD group, which demotes the result. Such results seem a bit confusing and were indeed not expected. Linear HIIT caused greater adaptations in agility than the agility-oriented COD programs. Table 2 shows differences between the initial and the final measurements in both groups.

Table 2. Difference between the initial and final measurements by the group - longitudinal study phase.

Groups	LHIIT (n= 30)				COD (n= 30)			
	Mean	SD	t	p	Mean	SD	t	P
93639 1 (s)	8.23	0.28	3.488	0.002*	7.99	0.24	1.33	0.194
93639 2 (s)	8.17	0.30			7.94	0.30		
505 1 (s)	2.70	0.14	4.365	0.000*	2.69	0.13	3.33	0.002*
505 2 (s)	2.65	0.14			2.64	0.16		
20-yard 1 (s)	4.71	0.21	5.090	0.000*	4.80	0.16	4.42	0.000*
20-yard 2 (s)	4.64	0.23			4.75	0.18		
CMJ 1 (cm)	43.80	0.25	-1.004	0.324	43.76	0.20	-7.72	0.000*
CMJ 2 (cm)	56.89	71.29			43.90	0.18		
FJ 1 (cm)	41.70	0.33	-2.177	0.038*	41.87	0.37	-1.31	0.199
FJ 2 (cm)	41.84	0.40			41.96	0.38		
SJ 1 (cm)	40.54	0.24	-4.838	0.000*	40.62	0.33	-7.68	0.000*
SJ 2 (cm)	40.70	0.35			40.70	0.30		
S5m 1 (s)	1.46	0.23	2.889	0.007*	1.38	0.19	-0.41	0.686
S5m 2 (s)	1.44	0.23			1.39	0.25		
S10m 1 (s)	2.40	0.23	6.637	0.000*	2.35	0.21	6.29	0.000*
S10m 2 (s)	2.37	0.24			2.30	0.21		
S20m 1 (s)	3.75	0.31	6.248	0.000*	3.77	0.30	5.18	0.000*
S20m 2 (s)	3.67	0.34			3.69	0.34		

t: t-test value; p: level of significance; 1: initial measurement; 2: final measurement; *: significant value; 93639: 9-3-6-3-9 test; 505: agility test 505; 20-yard: 20-yard agility assessment test; CMJ: counter-movement jump; FJ: free jump; SJ: squat jump; S5M: 5 meter sprint; S10m: 10m sprint; S20m: 20m sprint.

The LHIIT group took significant advantage in the final results of 20-yard, while the relations between the other variables remained similar. As in the start, the COD group still has an advantage in the 93639 test, although the difference is reduced by 0.1. Both groups significantly improved in many variables and analyzed programs should be used accordingly. Differences in only the final measurements between the groups can be seen in Table 3. Significant differences were found in both 93639 and 20-yard agility tests.

Table 3. Differences between the groups in the final results after the treatment.

Variables	Mean 1	Mean 2	SD 1	SD 2	t	P
93639 2 (s)	8.17	7.94	0.30	0.30	2.885	0.005*
505 2 (s)	2.65	2.64	0.14	0.16	0.357	0.722
20-yard 2 (s)	4.64	4.75	0.23	0.18	-2.106	0.040*
CMJ 2 (cm)	56.89	43.90	71.29	0.18	0.998	0.323
FJ 2 (cm)	41.84	41.96	0.40	0.38	-1.175	0.245
SJ 2 (cm)	40.70	40.70	0.35	0.30	0.044	0.965
S5m 2 (s)	1.44	1.39	0.23	0.25	0.753	0.454
S10m 2 (s)	2.37	2.30	0.24	0.21	1.105	0.274
S20m 2(s)	3.67	3.69	0.34	0.34	-0.276	0.783

t: t-test value; p: level of significance; 2: final measurements; 93639: 9-3-6-3-9 test; 505: agility test 505; 20-yard: 20-yard agility assessment test; CMJ: counter-movement jump; FJ: free jump; SJ: squat jump; S5M: 5 meter sprint; S10m: 10m sprint; S20m: 20m sprint; *: significant value.

DISCUSSION

The initial descriptive data analysis revealed specific differences between the groups' fitness levels. Still, despite the differences, groups were relatively evenly distributed, and the study was appropriately balanced at the outset. In the

longitudinal study phase (Table 2), the LHIIT group demonstrated significant improvements in eight out of nine variables, which is undoubtedly significant in practice. Notably, linear HIIT programs enhanced sprint, agility, and certain plyometric abilities more effectively than the agility-focused COD programs. In contrast, the COD group demonstrated significant improvements in six variables, particularly in tests related to agility and speed, such as the 505, 20-yard, SJ, S10m, and S20m tests. Unexpectedly, the COD group even experienced a decline in the S5m variable by 0.1, contrasting with the overall improvements in other variables. This unexpected result warrants further investigation and consideration in interpreting the effectiveness of the training programs. There has been much interest lately in the impacts of different HIIT programs on the various abilities within team sports. A recent review (24) reported contrary results regarding agility in football, where two studies deny HIIT effectiveness while one supports it. There is one fresh study (25) with almost the same design as this one regarding Serbian female football players. Both interventions significantly improved speed over 10m, 20m, 30m, Pro-agility, Zig-zag, RSAavg, fatigue index, VO_2max, and velocity at 30–15 IFT. In the end, the COD group did not achieve superior improvements in any of the measurements, and the authors concluded that different types of HIIT training may have a positive effect on the physical performance of elite female football players. Interestingly, both groups improved the vertical jump in all three variables. At the same time, the magnitude of response in all three measured tests for LHIIT ranged from 8.0% to 9.9% and 10.0% to 13.7% for COD, respectively, which is far greater progress than in this study (Table 2).

Their work suggests variable results of HIIT programs in football, which indicates the importance of adapting training programs to the specific needs of female athletes. This supports the positive effects of HIIT programs on speed, agility, aerobic endurance, and fatigue reduction. An essential aspect of HIIT programs is their specific adaptation to intense exercises, which is especially emphasized in LHIIT programs that effectively improve maximum speed and plyometric abilities such as jumps. On the other hand, COD programs emphasize the development of agility and quick reactions, which is crucial for dynamic situations in the field.

One of the critical aspects of HIIT programs is their ability to improve motor skills through specific adaptations to intense exercises. Linear HIIT (LHIIT) programs, which include straight sprints and standard intervals, are particularly effective for improving maximum speed (Vmax) and plyometric abilities such as the jump (SJ). These abilities are crucial for female soccer players, as they allow for the quick changes of pace and explosive movements that are common throughout the game. On the other hand, HIIT programs with a change of direction (COD) emphasize the development of agility and quick reactions, which is extremely important for players to quickly change direction to avoid opponents or react to changes in the game. These workouts improve physical abilities, coordination, and balance, which is critical to reducing the risk of injury (26, 27).

Finally, such results agree with the obtained results from this study, as results indicate a similar impact of linear and/or COD programs on the analyzed velocity and agility-related variables.

CONCLUSION

Overall, the results of this study suggest that both linear HIIT and COD programs can be effective in enhancing physical abilities in team sports, particularly in sprint, agility, and plyometric abilities. Still, the application of selected program may depend on the specific needs and goals of the athletes and the sport. Furthermore, the unexpected decline in the S5m variable in the COD group warrants further investigation and consideration in interpreting the effectiveness of the training programs. The findings of this study provide valuable insights into the effects of different HIIT programs on physical performance in team sports. By understanding the strengths and weaknesses of each program, coaches and athletes can make informed decisions about which training methods to use to optimize their performance. Further research may explore the underlying mechanisms contributing to the observed differences in performance outcomes between the linear HIIT and COD programs. Additionally, longitudinal studies tracking performance changes over an extended period could provide valuable insights into the sustainability and long-term effects of

different training modalities on athletic performance.

APPLICABLE REMARKS

- The research fills a literature gap and offers a scientific, theoretical, and practical contribution to women's football.
- HIIT training with directional changes and HIIT training without directional changes are practical for enhancing motor abilities, specifically agility.
- When implemented independently, the study delivers relevant information about these two types of training, offering a clear understanding of their specific effects.

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AUTHORS' CONTRIBUTIONS

Study concept and design: Marko Erceg, Goran Sporiš, Davorin Antonić. Acquisition of data: Davorin Antonić. Analysis and interpretation of data: Marko Erceg, Grgur Višić, Goran Vučković, Marko Pocrnjič. Drafting the manuscript: Grgur Višić, Onur Akman. Critical revision of the manuscript for important intellectual content: Goran Sporiš, Davorin Antonić, Fredi Fiorentini. Statistical analysis: Grgur Višić, Marko Erceg, Damir Jurko, Halasi Szabolcs. Administrative, technical, and material support: Halasi Szabolcs, Goran Vučković, Marko Pocrnjić, Onur Akman, Davorin Antonić. Study supervision: 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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