

Ann Appl Sport Sci 13(3): e1430, 2025. e-ISSN: 2322-4479; p-ISSN: 2476-4981



ORIGINAL ARTICLE

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

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Submitted August 29, 2024; Accepted November 20, 2024.



KEYWORDS

Soccer,
Performance,
Agility,
Plyometric Exercise,
High-Intensity Interval
Training,
Female,
Professional Athletes.

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 two groups: 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 the application of high-intensity actions, including accelerations, decelerations, jumps, and rapid changes in direction of movement during 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

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game (2). Such performance consists of many specific high-intensity activities. Most high-intensity activities occur during critical moments, such as when competing for the ball, executing 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 specific 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, highinterval training (HIIT) creates intensity appropriate high-intensity stimuli, which closely align with 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 highintensity activities, much like in HIIT. Some authors believe that HIIT is an important component for optimal development in female football players, whose sports require a combination of long-term endurance and highintensity 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, including accelerating, decelerating, jumping, and making 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 examining the impact of HIIT on the motor abilities of senior female football players.

Therefore, the primary objective of this investigation is to assess the impact of two distinct 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 conducted in accordance with the principles outlined in the Declaration of Helsinki. All examinees signed a statement expressing their willingness to participate in all 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 at the time of the research, and written consent was obtained prior to any experimental work.

Procedure. Anthropometric and aerobic capacity testing were initially applied to gain a clear anthropological picture of the selected athletes. Body height was measured with the Martin Anthropometer in the "Frankfurt horizontal" position. Furthermore, the Tanita diagnostic scale (BC-760) measured body weight and body fat. Aerobic capacity levels were estimated using a 30-15 intermittent fitness test (IFT), and subsequently, the maximal aerobic velocity and VO2max were derived.

Motor abilities to track were chosen according to the football performance demands, primarily agility, explosive power, and running velocity. The running velocity was measured using photocells (Witty, Microgate, Italy) during sprints executed 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 participated in specific HIIT programs for four weeks, twice a week, on Tuesdays and Thursdays. Training programs were performed under the authority of their football coaches and coaching teams. Testing was conducted at the Faculty of Kinesiology in Zagreb, at the Diagnostic Center, and on the football fields of ŽNK Split, ŽNK Osijek, and NK Neretva-Metković. The subjects began with their

dominant leg from a semi-high or medium start, while the group performing 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. This detailed assessment was conducted by a team of experienced assessors from the diagnostic organization, who received valuable assistance and collaboration from the club's coaches. 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 underwent anthropometric measurements and the 30-15IFT test. At the same time, the maximal aerobic velocity (MAV) (22), as well as the VO₂max (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. anthropometric and motor ability measurements were performed 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.

After the initial testing phase, the training program consisted of 15 seconds of HIIT training at 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 retested to detect any 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 were analyzed using Statistica 14.0. The first phase involved estimating descriptive statistics for the total sample. Student t-tests were used to determine potential 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 were analyzed, as shown in Table 1 below.

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 ₂ max 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; VO₂max: 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 the analyzed variables, as no significant differences were found between the mean results in most variables. Still, the LHIIT group had greater initial results in body fat, VO₂max, and 93639. This means that the COD group has better initial agility in this test, while the LHIIT group has bigger bodies, which results

in greater VO₂max 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 appears that linear HIIT programs enhance sprint, agility, and specific plyometric abilities;

COD programs, on the other hand, led to improvements 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. These results seem somewhat

confusing and were indeed unexpected. Linear HIIT resulted in greater adaptations in agility compared to the agility-oriented COD programs. Table 2 presents the differences between the initial and 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 | р | 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 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 | 1.004 0.324 - | 43.76 | 0.20 | -7.72 | 0.000* |
| CMJ 2 (cm) | 56.89 | 71.29 | 1.004 | | 43.90 | 0.18 | | |
| FJ 1 (cm) | 41.70 | 0.33 | 2.177 | 7 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 | 8 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 | 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 | 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 | 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 the 20-yard, while the relations between the other variables remained similar. As at the start, the COD group still has an advantage in the 93639 test, although the difference has been reduced by 0.1. Both groups

demonstrated significant improvement in several variables, and the analyzed programs should be utilized accordingly. Differences in the final measurements between the groups are evident in Table 3. Significant differences were found in both the 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 in the fitness levels of the

groups. 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 a notable and significant finding 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, 20yard, 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 consideration in interpreting the effectiveness of the training programs. There has been considerable interest lately in the effects of different HIIT programs on various abilities within team sports. A recent review (24) reported conflicting results regarding agility in football, with two studies denying the effectiveness of HIIT while one supports it. A recent study (25) with a design similar to this one has been conducted regarding Serbian female football players. Both interventions significantly improved speed over 10m, 20m, and 30m, as well as Pro-agility, Zig-zag, RSAavg, fatigue index, VO2max, and velocity at the 30-15 IFT. Ultimately, the COD group did not achieve improvements in anv measurements, and the authors concluded that different types of HIIT training may have a positive impact on the physical performance of elite female football players. Interestingly, both groups showed improvement in the vertical jump across 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, highlighting the importance of tailoring 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 are 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 enable 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 are crucial for players to quickly change direction to avoid opponents or respond to game changes. These workouts enhance physical abilities, coordination, and balance, which are crucial in reducing the risk of injury (26, 27).

Finally, these results align with the findings from this study, as they 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 a selected program may depend on the specific needs and goals of the athletes and the sport in question. 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.

ACKNOWLEDGMENTS

The Croatian Science Foundation under Project Grant Number supported this work. [IP2020-02-3366]. The sponsors had no role in the study design, data collection, analysis, decision to publish, or manuscript preparation.

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.

FUNDING/SUPPORT

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 conducted in accordance with the principles outlined in the Declaration of Helsinki. All examinees signed a statement expressing their willingness to participate in all 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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