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ORIGINAL ARTICLE

The Effect of Change-of-Direction on Specific Motor Abilities in Senior Female Football Players: A Comparison with Linear HIIT

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ABSTRACT

Background. High-intensity interval training (HIIT) is a popular method in football training aimed at enhancing ball-specific agility abilities. This study evaluated the effectiveness of linear HIIT (LHIIT) and change-of-direction HIIT (COD) protocols in improving these abilities in senior female football players. **Objectives.** The main objective was to compare the impacts of LHIIT and COD HIIT programs on ball-specific agility performance metrics. **Methods.** The study involved 60 senior female football players, divided equally into two groups: LHIIT (control) and COD (experimental). Initial and final measurements were conducted using ball-specific agility tests, specifically the M93639, M505, and M20-yard tests. Both groups participated in a four-week HIIT training program. **Results.** Both HIIT programs significantly enhanced ball-specific agility in all measured variables. The LHIIT group showed slightly greater improvements in the M93639 test, while improvements in the M505 and M20-yard tests were identical between the two groups. **Conclusion.** Both linear and COD HIIT protocols effectively enhance ball-specific agility in senior female football players. LHIIT showed a slight advantage in one of the specific agility tests, but overall, both types of HIIT programs contributed significantly to performance improvements. The study highlights the importance of integrating repetitive, explosive, and lower-body strength exercises, along with specific agility and plyometric drills, into HIIT protocols for optimizing physical conditioning and reducing injury risks in female football players. Coaches and sports scientists are encouraged to tailor training programs to meet the unique needs of female football players for optimal performance and injury prevention.

INTRODUCTION

In the realm of sports performance training, the debate between the effectiveness of change of direction exercises versus linear High-Intensity Interval Training (HIIT) has been a topic of interest, particularly in the context of senior female football players, often as compared with sprint,

plyometric, and agility performance parameters. As is known, acceleration and sprint performance are associated with maturity status (1), but age differences tend to perish when they reach senior level- for instance, collegiate female players shared similar results in the 505 test, regardless of age (2). In other words, such abilities become and remain one of the key determinants for the performance of female football players at the senior level. The ability to swiftly change direction and maintain specific motor abilities is crucial for success in football, making it essential to explore the impact of different training methodologies on these aspects. When discussing the physical conditioning of female football players, it is essential to highlight the importance of comprehensive training programs that address the sport's specific needs and demands. Specific motor abilities, such as reactive agility, running velocity, running acceleration, dynamic coordination, and balance with the ball, play a vital role in the final performance of senior female football players on the field. These abilities are essential for executing precise movements during gameplay.

During a game, players often cannot predetermine their movement patterns due to the need to react to unpredictable external stimuli, such as opponents, teammates, or the ball. This necessity for rapid and precise reactions, known as reactive agility (RA), involves significant cognitive-perceptual skills like visual processing, spatial awareness, reaction time, perception, and anticipation (3-5). Despite this, change-of-direction speed (CODS) provides the physiological and mechanical foundation for agility. Studies suggest that preplanned COD movements impose less strain on the knee compared to reactive sidestepping, thus lowering the risk of lower limb injuries (6, 7).

Speaking of agility, there are a lot of generic tests frequently used in soccer practice (8) due to their applicability, simplicity, and less-or-more satisfactory transfer to on-field conditions. In soccer, the practical usage of agility often occurs in various ball-involving situations. Unfortunately, there is an evident lack of studies involving performance (sprint, plyometric, agility) testing with a ball. Some of the well-known generic agility tests were modified with just a soccer ball to gain an environment like the real game (9). For example, in the football version of the 505 test with a ball, players are required to dribble the ball through a slalom course of cones, make a quick turn at the end, and sprint back to the starting point. This test not only evaluates the player's ability to change direction quickly and maintain control of the ball but also simulates game-like situations where players need to navigate through defenders and execute rapid changes in direction while maintaining possession. There are, however, no studies up to date determining the impact of HIIT protocols on possible outcomes of ball-related agility in female soccer players.

So far, this study aims to investigate whether COD HIIT exercises can enhance football-specific agility abilities with the ball more effectively than linear HIIT in senior female football players.

MATERIALS AND METHODS

Ethics Committee approval. The Ethics Committee of the Faculty of Kinesiology at the University of Zagreb approved this study, which was conducted in compliance with the Helsinki Declaration. All participants provided written consent, indicating their willingness to undergo the testing procedures involved in this research.

Participants. The acquired participants for this study 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). Every participant was at least 18 years old (24±4.66; median 23) when the research occurred, and written consent was provided before the experimental work.

Procedure. Anthropometric and aerobic capacity tests 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. Further, Body weight and Body fat were estimated with the TANITA diagnostic scale (BC-760). Aerobic capacity levels were estimated using a 30-15 intermittent fitness test (IFT), while the maximal aerobic velocity and VO_2max were derived thereafter.

Agility-related motor manifestations were chosen according to the football performance demands, where the specific ball-involving tasks play a crucial role in final success. The variations of agility with the ball were estimated through three tests: Modified test 9-3-6-3-9 (M93639) (9), Agility test 505 (M505) (Nimphius et al, 2017), and 20-yard agility test (M20-yard) (10). Photoelectric cells (Witty photocell, Microgate, Bolzano, Italy) were

used to detect the precise values. The conduction of these tests is structurally the same as the original ones, but in this case, participants need to lead a football through the tests.

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 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 in the group that did the turn, it alternated with the dominant leg and then the weaker leg. Larus Sport, a firm specializing in sports diagnostics, fitness, medicine, and rehabilitation, conducted a comprehensive assessment. A skilled team from the diagnostic organization, supported by club coaches, ensured precise and thorough data collection, enhancing the measurement process's overall success. In the first phase, subjects were tested through the anthropometric measurements and 30-15IFT, while the maximal aerobic velocity (MAV) (11), as well as the VO_2max (12), were estimated a priori to adapt the following training programs. The main data consisted of the football-specific agility measurements, applied initially and after the treatment. Both 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 process of measuring and data analysis.

The training program after the initial testing phase 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 were analysed through the software Statistica 14.0. The first step included a Descriptive statistics analysis of the initial results achieved by selected groups. The second step involved a dependent Student t-test for the determination of intra-group differences after the treatment; for further determination of the possible final differences in motor abilities between the groups, an independent Student t-test was applied. Data will be available through personal communication with the authors.

RESULTS

Data obtained through initial measurements are presented in Table 1.

Table 1. Initial descriptive characteristics of two groups- the first phase of the study.

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 (ml/kg/min)	52.64*	2.39	51.19	3.12
M93639 1 (s)	10.26*	0.31	9.85	0.45
M505 1 (s)	3.70	0.14	3.69	0.13
M20-yard 1 (s)	5.71	0.21	5.76	0.21

*: significant difference between groups; 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.

Groups appear to be similar in terms of body height, weight, initial M505 and M20-yard results; however, there are certain differences in body fat, VO_2max, and initial M93639 results.

Interestingly, both LHIIT and COD HIIT groups had significant progress after the treatment, with similar and/or the same relative progress. The COD group had a slightly smaller improvement in the M93639 test, which is not the case for the LHIIT group. The reason for such results may be found in better initial results regarding the COD group, which means they had slightly less space for development.

A comparison of final results, which can be seen in both Table 2 and Table 3, revealed a significant difference only in the M93639 test in favour of the LHIIT group, with no difference between the M505 and M20-yard tests between the groups at all.

Table 2. Pre to post-treatment progress within a specific group, longitudinal research phase.

Groups	LHIIT (n=30)				COD (n=30)			
	Mean	SD	t	p	Mean	SD	t	P
M93639 1 (s)	10.26	0.31	4.549	0.000	9.85	0.45	1.876	0.071
M93639 2 (s)	10.15	0.26			9.77	0.40		
M505 1 (s)	3.70	0.14	4.347	0.000	3.69	0.13	4.047	0.000*
M505 2 (s)	3.62	0.20			3.61	0.20		
M20-yard 1 (s)	5.71	0.21	7.484	0.000	5.76	0.21	5.618	0.000*
M20-yard 2 (s)	5.58	0.20			5.63	0.22		

*: significant value; 1: initial measurement; 2: final measurement; SD: standard deviation: t: t-test value; 93639: 9-3-6-3-9 test; 505: agility test 505; 20-yard: 20-yard agility assessment test; p: level of significance.

Table 3. Final difference between the selected groups tested through the t-test.

Variables	Mean 1	Mean 2	SD 1	SD 2	t	P
M93639 2 (s)	10.15	9.77	0.26	0.40	4.234	0.000*
M505 2 (s)	3.62	3.61	0.20	0.20	0.241	0.810
M20-yard 2 (s)	5.58	5.63	0.20	0.22	-0.987	0.328

SD: standard deviation; 2: final measurement; t: t-test value; 93639: 9-3-6-3-9 test; 505: agility test 505; 20-yard: 20-yard agility assessment test; p: level of significance.

DISCUSSION

The incorporation of the ball within tasks adds a dynamic element to the traditional agility tests, providing a more realistic assessment of the specific motor abilities needed for success on the football field. It seems that both LHIIT and COD HIIT programs almost equally enhanced a significant upgrade in terms of ball-specific agility. The M93639 test seems to be sensitive for assessing the progress in linear HIIT protocols, but not for the COD HIIT protocols (Table 2). However, the M93639 demonstrated significant differences between the groups, in both initial and final measurements, where the COD group demonstrated a better performance (Tables 1 and 3).

The groups were similar in height, weight, and initial scores of M505 and M20 yards, but differed in body fat, VO_2max, and initial scores of M93639. After treatment, both the LHIIT and COD groups saw significant improvements, with relatively similar improvements. The CCP group achieved a slightly smaller improvement in the M93639 test compared to the LHIIT group, which could be due to better initial results in the CCP group, indicating a lower potential for improvement in this group. The only significant difference was found in the M93639 test, where the LHIIT group showed an advantage, while there was no difference in the M505 and M20 yards tests between the groups.

The modified football versions of the 505 and 20-yard tests appear to be a valuable tool for assessing a player's agility, ball control, and overall performance on the field, as the progress of both groups enhanced equally following the treatment (M505 by 0,8; M20-yard by 0,13 -in each group) (Table 2). On the other hand, greater progress was expected in COD due to the inter- and intra-muscular coordination, but results proved the contrary. Regardless of linear or COD movement, the literature suggests that acceleration, agility, sprint speed, strength, and many other factors are in continuous interrelation and overlap. A study regarding elite female soccer players revealed that the performance variables (10 and 20 m speed, mean 505, and COD deficit mean) can be predicted with almost 100% accuracy (i.e., adjusted R^2>0.999) using various combinations of the predictor variables (DJ height, CMJ height, SJ height, and lean body mass) (13). Researchers from the USA tried to determine predictors of athletic performance in Collegiate women's soccer players, and absolute and relative strength were compared to agility and sprint performance. Significant correlations were discovered between absolute lower-body strength and the 505 test (Right: r=−0.51, p<0.05; Left: r=−0.59, p<0.05), as well as between the relative lower-body strength and 505 test (Right: r=−0.58, p<0.05; Left: r=−0.67, p<0.01) (14). A recent study (15) reported acceleration in the first 10 m of a sprint as a significant predictor of COD performance (r^2=28% to 50%; p<0.01), while significant correlations were found between COD180 performance and % COD deficit,

acceleration, linear speed, and horizontal jump performance ($r=-0.59$ to 0.70; $p<0.05$).

A crucial element of anaerobic fitness in soccer is the capacity to quickly recuperate between bursts of intense activity, enabling players to sustain a high level of performance. High-Intensity Interval Training (HIIT) has proven to be effective in enhancing this capacity, boosting phosphocreatine reserves and the rate of ATP resynthesis, both essential for anaerobic endurance (16). Moreover, HIIT exercises that incorporate directional changes help improve the biomechanical aspects of movement, thereby reducing the risk of injuries associated with high-intensity actions and abrupt changes in direction (17). Additionally, this type of training can enhance cognitive sharpness and the ability to make rapid decisions on the field, which is vital in the fast-paced nature of a soccer match (18).

Specific agility with the ball is a key component of football performance, as female players must not only be fast and agile, but also be able to control the ball during these rapid changes of direction and acceleration. This complexity requires the development of high-intensity technical skills, which HIIT workouts effectively encourage. Introducing the ball into HIIT workouts can significantly improve the ability of female soccer players to maintain control of the ball during high-intensity situations. For example, exercises that combine sprinting with ball handling or changing direction with ball passing can provide additional challenges that improve technical performance under pressure. Therefore, physical conditioning for female football players should include a combination of repetitive, explosive, absolute, and relative strength (primarily lower-body), various generic and specific agility drills, plyometric drills, and other specific skills and abilities. Further, such drills can be successfully performed as HIIT protocols, both linear and COD-oriented ones. These HIIT protocols were designed primarily to enhance overall performance and second to reduce the risk of injuries associated with sudden changes in direction and high-intensity movements.

CONCLUSION

It can be concluded that both linear and COD HIIT protocols enhance ball-specific agility almost equally. However, the linear HIIT programs demonstrated slightly higher applicability regarding M93639 manifestation, which may be influenced by a better starting position of the COD group may influence. Lastly, both selected HIIT programs can be successfully implemented in the physical conditioning of female football players. Understanding the impact of various HIIT training methods on enhancing these specific motor abilities is crucial for optimizing the athletic performance and overall well-being of senior female football players. Research in this area may focus on evaluating the effectiveness of different HIIT methods and programs for female football players, as well as identifying factors that may influence their physical conditioning regarding specific agility, such as age, playing position, and level of competition. By understanding the unique physical conditioning requirements of female football players, coaches and sports scientists can develop tailored training programs that optimize performance and minimize the risk of injuries.

APPLICABLE REMARKS

- The research complements existing literature and makes significant contributions to women's football, an area previously dominated by studies on male players.
- It highlights that both linear and change of direction (COD) HIIT protocols enhance ball-specific agility almost equally, although linear HIIT shows slightly higher applicability in certain areas, possibly due to better starting conditions in the COD group.
- Both HIIT programs can be effectively integrated into the physical conditioning of female football players.
- Understanding the impact of various HIIT training methods on specific motor abilities is essential for optimizing athletic performance and overall well-being. Coaches and sports scientists can use these insights to develop tailored training programs, enhancing performance and reducing injury risks.

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AUTHORS' CONTRIBUTIONS

Study concept and design: Aleksandar Miletić, Marko Erceg, Goran Sporiš, Davorin Antonić. Acquisition of data: Davorin Antonić. Analysis and interpretation of data: Marko Erceg, Grgur Višić, Goran Vučković, Robert Bobinec. Drafting the manuscript: Grgur Višić, Aleksandar Miletić. 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, Robert Bobinec, 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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