The impact of running-based high-intensity interval training with changes of direction on physical performance of female soccer players

El impacto del entrenamiento por intervalos de alta intensidad basado en la carrera con cambios de dirección en el rendimiento físico de las jugadoras de fútbol

Authors

Andrea Paprancová [1]
Jaromír Šimonek [1]
Ľubomír Paška [1]
Monika Czaková [1]
Matúš Krčmár [1]

[1] Constantine the Philosopher University in Nitra (Slovakia)

Corresponding author:
Andrea Paprancová
apaprancova@ukf.sk

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Abstract

The aim of this study was to determine the impact of running-based high-intensity interval training with changes of direction on the physical performance of female soccer players. Twenty-four female amateur football players (age: 19.25 ± 2.07 years; height: 165.20 ± 6.27 cm; weight: 59.04 ± 6.62 kg) were divided into two groups (experimental – HIIT COD and control – CON) and participated in the study. The experimental period lasted 8 weeks, during which twelve sessions of HIIT COD were implemented. The physical tests included 10m, 20m, and 30m sprints, the 30-15 IFT, RAT-O (offensive agility), RAT-D (defensive agility), RAT-Y (Y agility), and the 5-0-5 COD test.

The results indicated that, compared to the CON group, statistically significant changes between the pre- and post-tests occurred in the HIIT COD group for all tests except the 10m sprint. A comparison between the HIIT COD and CON groups revealed a significant group-by-time interaction in the 30-15 IFT ($F = 44.36$, $p < 0.001$). Post-hoc analysis showed a significant difference in favor of the HIIT COD group ($t = 4.864$, $p = 0.002$). A significant group-by-time interaction was also found in the 5-0-5L test ($F = 39.60$, $p < 0.001$). Post-hoc tests showed a significant improvement in favor of the HIIT COD group over the CON group ($t = -5.364$, $p = 0.001$).

In conclusion, this study shows that the implementation of short-duration, running-based HIIT COD into regular training can improve short linear sprints, agility, COD, and intermittent endurance performance in female soccer players.

Keywords

Female football; agility; speed abilities; running-based interval training.

Resumen

El objetivo de este estudio fue determinar el impacto del entrenamiento en intervalos de alta intensidad basado en carrera con cambios de dirección sobre el rendimiento físico de jugadoras de fútbol femenino. Veinticuatro jugadoras de fútbol amateur (edad: 19.25 ± 2.07 años; altura: 165.20 ± 6.27 cm; peso: 59.04 ± 6.62 kg) fueron divididas en dos grupos (experimental – HIIT COD y control – CON) y participaron en el estudio. El período experimental tuvo una duración de 8 semanas, durante las cuales se implementaron doce sesiones de HIIT COD (15s - 15s con 95-105% VIFT – velocidad final durante la prueba de fitness intermitente 30-15). Las pruebas físicas incluyeron sprints de 10m, 20m y 30m, el 30-15 IFT, RAT-O (agilidad reactiva ofensiva), RAT-D (agilidad reactiva defensiva), RAT-Y (agilidad reactiva tipo Y) y la prueba 5-0-5 COD. Los resultados indicaron que, en comparación con el grupo CON, se produjeron cambios estadísticamente significativos entre las pruebas pre y post en el grupo HIIT COD en todas las pruebas, excepto en el sprint de 10m. La comparación entre los grupos HIIT COD y CON reveló una interacción significativa entre el grupo y el tiempo en el 30-15 IFT ($F = 44.36$, $p < 0.001$). El análisis post-hoc mostró una diferencia significativa a favor del grupo HIIT COD ($t = 4.864$, $p = 0.002$). También se encontró una interacción significativa entre el grupo y el tiempo en la prueba 5-0-5L ($F = 39.60$, $p < 0.001$). Las pruebas post-hoc mostraron una mejora significativa a favor del grupo HIIT COD sobre el grupo CON ($t = -5.364$, $p = 0.001$).

En conclusión, este estudio demuestra que la implementación de HIIT COD basado en carrera y de corta duración en el entrenamiento regular puede mejorar los sprints lineales cortos, la agilidad, los cambios de dirección y el rendimiento en resistencia intermitente en jugadoras de fútbol femenino.

Palabras clave

Fútbol femenino; agilidad; capacidad de velocidad; entrenamiento de intervalos basado en carreras.

Introduction

In the dynamic realm of modern soccer, where agility, speed, and endurance play pivotal roles in determining success on the field, the quest for optimal training methodologies is ceaseless. Female soccer players, in particular, face unique physiological challenges that necessitate tailored training approaches. Women´s soccer is one of the most dynamically growing sports in the world and has advanced significantly in terms of finance and media as a result, the demands for women's soccer as team sport have risen sharply (Ehnold et al., 2024; Stanković et al., 2023). The essence of soccer lies not only in the ability to sprint but also in the agility to navigate swiftly through ever-changing game scenarios. Two types of agility have been proposed: pre-planned and non-planned. In pre-planned agility, such as COD (change of direction), the player knows the movement pattern and can outperform the opponent using their physical abilities. In contrast, non-planned agility requires reacting to stimuli, such as the opponent's movements and the ball's trajectory. Studies show that these two qualities are not developed equally, with a low correlation between them (Matlák et al., 2016). Despite the low correlation between planned and non-planned agility, both are crucial for meeting the demands of the game due to their occurrence in training and matches (Pojskic et al., 2018). Traditional conditioning process often fall short in addressing the multifaceted demands imposed by soccer, especially for female players who may encounter distinct biomechanical challenges. The integration of high-intensity interval training, coupled with direction changes, emerges as a promising avenue to bridge this gap (Milanović, Sporiš, Weston, 2015). Training protocols for females are not different from males, since female training programs have improved dramatically over the years (Yap & Brown, 2000). Changes in the movement mechanism of the arms or legs can influence linear action such as acceleration and velocity. Thus, the ability to develop speed quickly (acceleration) is an important component for supporting performance in a variety of sporting activities (Azmi & Kusnanik, 2018). Soccer is a sport where in athletes spend approximately 80–90% of their performance time at a low to moderate intensity and the remaining 10–20% in intermittent bouts of high-intensity running and very high-intensity running (Bradley et al., 2010). Regarding the movement profile, studies show that female soccer players cover a total distance of 9631 ± 175 m, 2407 ± 125 m in high-speed running, 338 ± 30 m in sprint distance, 68.9 ± 17.1 m in acceleration, and 81.3 ± 21.0 m in deceleration (Hewitt et al., 2014; Choi & Joo, 2022; Principe et al., 2021).

HIIT has gained prominence for its efficacy in enhancing cardiovascular fitness, metabolic capacity, and overall athletic performance. However, a gap exists in the literature concerning the specific adaptations of female soccer players to HIIT programs incorporating changes of direction (Impellizzeri, Rampinini, Marcora, 2005). This study seeks to address this gap by investigating the effects of such a training protocol on key performance indicators such as speed, agility, endurance, and injury prevention among female soccer players (Gabbett, 2016). Understanding the physiological responses to running-based HIIT with changes of direction is crucial not only for optimizing training protocols but also for minimizing injury risks associated with abrupt directional shifts (Mujika, Padilla, 2000). As female athletes exhibit unique neuromuscular characteristics, an in-depth exploration of the interplay between high-intensity intervals and dynamic changes in movement patterns becomes imperative for tailoring training programs that align with their specific needs (Bangsbo, Iaia, Krustup, 2008). Stankovic et al. (2023) conducted a meta-analysis focused on running-based HIIT training and its effects on body composition and physical performance. Of the 13 studies included in their analysis, they found that HIIT improved VO2max in 5 studies, RSA (repeated sprint ability) in 3 studies, and COD speed in 5 studies. Results for explosive strength and body composition varied the most and were inconsistent. Specifically, Nayıroğlu et al. (2022) directly compared small-sided games and running-based HIIT in U19 female soccer players and found that neither group achieved significantly better performance, but both groups showed improvements in CMJ (countermovement jump), hops, RSI (reactive strength index), and VIFT (maximal velocity reached during the incremental fitness test).

To our knowledge, only a few studies have investigated the impact of running-based HIIT with changes of direction on female soccer players. Based on the limited number of studies, we hypothesized that the group performing the running-based HIIT COD program, in addition to their regular training routine, would show significant improvements primarily in the 30-15 IFT, both within and between groups, compared to the control group. We also hypothesized significant improvements in pre-planned COD, both within and between groups.

Method

Study design

This study is a randomized controlled trial aimed at assessing the effects of a high-intensity interval training with changes of direction (HIIT COD) program on performance metrics in female soccer players. The participants included 24 female players from the GFC Regional Academy. Inclusion criteria were outfield players who were able to complete at least 80% of the training sessions. Exclusion criteria included goalkeepers and any new training stimuli introduced outside the study.

Participants

Twenty-four female football players participated in this study. Before commencing the experiment, the participants were randomly divided into experimental group - HIITCOD (n=12, age: 20.58 ± 1.88 years, body mass: 61.17 ± 7.80kg, body height: 164.92 ± 5.33cm) and control group – CON (n=12, age: 17.92 ± 1.24 years, body mass: 56.93 ± 4.58kg, body height: 165.50 ± 7.32cm). All players were selected from an amateur football team GFC Regional academy, which plays in the first Slovak women's league. Goalkeepers were excluded from the study due to the fact that they did not participate in the same training program as the rest of the team. All players involved in the research had to complete at least 80% of the training process. All the players received written informed consent with a detailed explanation of the objectives and the risks associated with the experimental program. Likewise, all coaches and players were acquainted with the purpose and nature of the research. During the experiment, coaches and players were asked not to implement any new training stimuli that could influence the results of our research. The research was approved by the GFC Regional Academy and a local research ethics committee, and the study was approved by University Ethic Committee (registration number: UKF-2020/1355-1:191013) to comply with the Declaration of Helsinki.

Procedure

Field Testing

The timing for 10, 20, and 30-meter sprint tests was recorded using the Witty wireless training timer (Microgate, Bolzano, Italy). Participants initiated the sprint with the toe of their preferred foot positioned 0.3 meters behind the starting line. Upon readiness, participants sprinted as quickly as possible until crossing the stop line. Each participant had two trials, and the best time from the two attempts was recorded. All measurements were conducted under standardized conditions on an artificial turf. The reliability of this test has previously been investigated using the intraclass correlation coefficient (ICC), which was 0.93 for the 10m sprint, 0.89-0.95 for the 20m sprint, and 0.93 for the 30m sprint (Moir et al., 2004). The reliability of the Witty wireless training timer was also previously reported in our study on the 5m, 10m, and 30m dashes, with ICCs and confidence intervals (CIs) of 0.97 (CI: 0.83–0.98), 0.99 (CI: 0.95–0.98), and 0.98 (CI: 0.95–0.99), respectively (Bakaľár et al., 2020).

The 30-15 Intermittent Fitness Test (IFT) comprises 30-second shuttle runs alternated with 15-second walking recovery intervals. Commencing at an initial speed of 8 km/h during the first 30-second shuttle run, the running speed incrementally rises by 0.5 km/h for each subsequent 30-second stage. Consequently, the running speeds for stages progress as follows: 8 km/h for stage 1, 8.5 km/h for stage 2, 9 km/h for stage 3, and so forth. Athletes engage in shuttle runs between two lines spaced 40 meters apart, guided by an audio cue in the form of a "beep." As participants advance through the stages, the time interval between beeps diminishes, reducing the time available to complete each shuttle and intensifying the speed of the test. In the testing area, two 3-meter zones positioned in the middle facilitate athletes in determining the required running speed, allowing them to adjust their pace accordingly, either accelerating or decelerating. The two 3-meter end zones, serving as turning lines, assist athletes in maintaining or adjusting their speed. During the 15-second recovery period, athletes walk forward towards the nearest 3-meter zone, the starting point for the subsequent running stage. Athletes must consistently reach the next 3-meter zone, either the middle one or the end zones. Failure to achieve this on three consecutive occasions results in elimination from the test. The reliability of this test has been previously investigated (ICC) of 0.91 (Čovič et al., 2016).

The 5-0-5 Change of Direction (COD) test involves a flying start, wherein the subject is granted a 10-meter lead before traversing the starting line and initiating the timer. Following the crossing of the

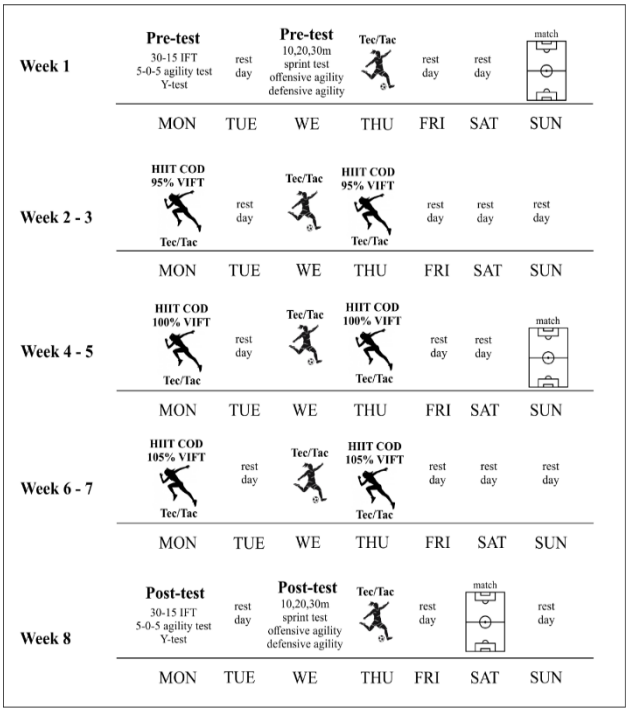
starting line, the photocells activate, prompting the participant to sprint for five meters, execute a 180° turn, and sprint an additional five meters. The timing of this sequence is recorded to the nearest 0.01 second. Each participant is afforded three attempts at the test. The Test 5-0-5 (COD) specifically evaluates the capacity for acceleration and deceleration through changes of direction. In the 5-0-5 COD test, participants execute directional changes on both their dominant and/or nondominant leg (preferred/nonpreferred leg). The timer commences when a participant first passes through the timing gate and concludes upon their subsequent passage upon returning. A one-minute recovery period is allocated between each attempt. The reliability of this test has already been investigated (ICC: 0.96) (Barber et al., 2016).

For assessing reactive agility, the following tests were employed: the reactive agility test (RAT-Y), which is the Y-agility test (Oliver & Meyers, 2009) using Witty Sem (Microgate Bolzano, Italy); the modified shuttle run with "offensive" movement (RAT-O) based on reactive stimuli (Sekulic et al., 2014); and the modified shuttle run with "defensive" movement (RAT-D) also based on reactive stimuli (Sekulic et al., 2014).

Training design

The training program included 8 microcycles, while each microcycle lasted for 7 days (Figure1).

Figure 1. Schematic illustration of training program across each microcycle across the 8-week training cycle. Tec/Tac = technical-tactical training, HIIT = high intensity interval training, COD = change of direction, VIFT = velocity obtained in 30-15IFT test



First and the last microcycle included pre-testing and post-testing sessions. After testing, players went through technical-tactical training. From second to seventh week, microcycles consisted of three training sessions each. On Mondays and Thursdays, players performed technical-tactical training, moreover experimental group HIITCOD applied experimental stimuli during the last twenty minutes. On Wednesdays, players completed technical-tactical training. Regarding technical-tactical training, in week 1, players performed preparatory exercises of a tactical nature and standard situations. In weeks 2 and 3, after HIIT, preparatory exercises to improve individual offensive and defensive game activities were conducted, and on Wednesdays, preparatory exercises to improve offensive game combinations were performed. Weeks 4 and 5 focused on preparatory exercises to improve individual offensive and defensive game activities, with Thursdays after HIIT including preparatory exercises of a tactical nature for the 4-3-3 game system and standard situations. In weeks 6 and 7, after HIIT on Monday and Thursday, preparatory exercises to improve individual offensive and defensive game activities were conducted, and on Wednesdays, preparatory exercises to improve defensive game combinations were

performed. In week 8, preparatory exercises of a tactical nature for the 4-3-3 game system and standard situations were carried out. During the first, fourth, fifth, and final weeks, players completed friendly matches. Tuesdays and Thursdays were rest days. It was ensured that all players received the same training routines, except for the HIITCOD group. The CON group completed the same training sessions as the HIITCOD group, except for the running-based high-intensity interval training with change of direction (Figure 1). All training sessions were performed on artificial turf.

Running based high-intensity interval training with change of direction

HIITCOD intervention consisted of three sets of four minutes of activity which were interspersed with three minutes of rest. Participants performed 8 repetitions in intensity of 15-second runs and 15-second rest during set duration. We also applied COD time loss of 0.7 seconds per 180 degrees turn. The intensity during the second and third microcycle was set at 95% of velocity obtained in the 30–15 intermittent fitness test (VIFT), in the fourth and fifth microcycle at 100% VIFT and in the sixth and seventh week at 105% VIFT (table 1).

Table 1. Characteristics of running-based high-intensity interval training with change of direction (HIITCOD)

HIIT COD	
Intensity 15s/15s with COD time loss of 0.7 seconds per 180 degrees turn	
Number of players	n = 12
Sets duration (min.)	4
Duration of recovery (min.)	3
Number of sets	3

Statistical analyses

The obtained data were processed using basic mathematical and statistical methods (arithmetic mean, standard deviation). The normality of the data distribution was assessed using the Shapiro-Wilk test. To assess statistical significance, a 2-way mixed ANOVA with repeated measures was used to evaluate within- and between-group differences. Statistical power to determine the optimal sample size was calculated using G*Power analysis (Faul et al., 2007). To achieve a power of 0.80 with an alpha of 0.05 and an effect size f of 0.25, the optimal number of subjects for 2 groups and 4 measurements is 24. An independent t-test was used to determine significant differences between the groups after the pre-training measurements. When a significant group-by-time interaction was found, the Tukey post-hoc test was performed to identify where the significant differences within or between the groups occurred. Effect sizes (Cohen's d) were calculated to estimate the meaningfulness of the comparisons between pre- and post-test results. The thresholds for effect size statistics were as follows: <0.2 = small, 0.5 – 0.8 = moderate, >0.8 = large (Cohen, 1992). All data analyses were performed using Jamovi (The Jamovi Project, 2024). Jamovi (Version 2.5) [Computer Software]. Retrieved from https://www.jamovi.org.

Results

The main results of this study are presented in Table 2. The study shows that, compared to the CON group, the HIIT COD group exhibited statistically significant changes between pre- and post-tests across all assessments except for the 10m acceleration performance. The control group did not achieve significant improvement, but there was a trend towards significant improvement in the offensive reactive agility test ($p = 0.057$, $d = 0.84$). However, a comparison between the groups revealed that the HIIT COD group showed significantly better improvement compared to the CON group only in the 30-15 IFT ($t = 4.86$, $p = 0.002$) and the 5-0-5L test ($t = -5.36$, $p = 0.001$). No other significant differences between the groups were recorded.

Table 2. Performance characteristics of the HIIT COD and CON groups after pre- and post-training measurements

Variable	Experimental Group (n=12)		Control group (n=12)	
	PRE	POST d (95% CI)	PRE	POST d (95% CI) F value
	mean ± sd	mean ± sd	mean ± sd	mean ± sd P value
10m (s)	1.99 ± 0.11	1.96 ± 0.09 0.79 (0.12 -1.43)	1.97 ± 0.09	1.96 ± 0.09 0.56 (-0.05 – 1.17) F = 3.13 p = 0.10
20m (s)	3.51 ± 0.12	3.49 ± 0.12** 1.78 (0.83 - 2.69)	3.48 ± 0.07	3.47 ± 0.07 0.27 (-0.31 – 0.84) F = 9.58 p = 0.01
30m (s)	4.96 ± 0.17	4.93 ± 0.18** 1.28 (0.49 -2.05)	4.97 ± 0.12	4.96 ± 0.13 0.14 (-0.43 – 0.70) F = 23.20 p = 0.01
30-15IFT (km/h)	17 ± 0.50	18 ± 0.50**$$ -2.68 (-3.91 -1.43)	17 ± 0.50	17 ± 0.50 0.51 (-1.10 – 0.10) F = 44.35 p= <0.001
RAT-O (s)	21.29 ± 0.89	21.19 ± 0.90** 1.33 (0.53 - 2.12)	21.65 ± 1.03	21.64 ± 1.03 0.84 (0.16 – 1.49) F = 16.24 p = 0.002
RAT-D (s)	21.90 ± 0.74	21.77 ± 0.72* 0.84 (0.16 - 1.49)	22.17 ± 0.72	22.17 ± 0.70 0.02 (-0.58 – 0.54) F = 6.40 p = 0.02
RAT-Y (s)	2.65 ± 0.12	2.62 ± 0.12** 2.01 (0.99 - 3.01)	2.73 ± 0.14	2.72 ± 0.13 0.08 (-0.48 – 0.64) F = 11.09 p = 0.007
5-0-5 R (s)	2.54 ± 0.10	2.48 ± 0.11** 3.76 (2.10 - 5.40)	2.57 ± 0.05	2.56 ± 0.05 0.30 (-0.28 – 0.87) F = 100.50 p = <0.001
5-0-5 L (s)	2.52 ± 0.10	2.43 ± 0.09**$$ 1.85 (0.88 -2.79)	2.58 ± 0.05	2.57 ± 0.05 0.19 (-0.37 – 0.76) F = 39.60 p = <0.001

Notes: *0.05 pre- to post- training; **0.01 pre- to post- training; $0.05 compared to the CON; $$0.01 compared to the CON; sd = standard deviation; CON = control group; d = cohen´s, effect size; RAT-O = offensive agility; RAT-D = defensive agility; RAT-Y = Y test, F = F statistic, p = probability value, CI = confidence interval, s = seconds, R = right, L = left

Discussion

The main aim of this study was to evaluate changes in multiple physical outcomes after completing a HIIT training protocol incorporating COD (change of direction). Table 2 shows that the experimental group, which performed the HIIT protocol, significantly improved all the results except 10m acceleration, whereas the control group did not. Several studies examined the effect of different modes of HIIT on various physical as well as physiological outcomes. The most similar study to our was performed by Stanković et al. (2024) who examined effects of linear and COD running-based HIIT on 10, 20 and 30m linear sprinting, various COD tests, vertical jump performance, repeated sprint ability and 30-15 IFT.

The main findings of their study shows that both groups significantly improved in all tests except for repeated sprint ability where only HIIT group which incorporated COD significantly improved in this test. However, direct comparison of groups in each test showed significant difference except for 10m sprint times changes in favor of the experimental group. Regarding sprint tests in the experimental group, we recorded 1.41% improvement in the 10m, 0.52% in the 20m, and 0.62% in the 30m sprint test. Our changes in the group that performed HIIT COD are much smaller compared to the Stanković et al. (2024) study where their changes ranged from 5.3% to 9.7% in the same tests. Possible explanation may be the total duration of the HIIT COD sessions. In our study total duration of HIIT COD was 12 minutes with gradual increase of the intensity of runs from 95% to 105% of VIFT compared to the 18 to 26 minutes of total duration in their study with a constant intensity at 100% VIFT. Slightly higher changes were noted in the 5-0-5 COD test where improvements in our study ranged from 2.37% to 3.49%. These results are closer to Stanković et al. (2024) study and very similar to the Nayıroğlu et al. (2022) study. In addition, it is well known that HIIT with or without COD implementation can significantly improve COD speed and/or COD deficit (Nayıroğlu at al. 2022, He et al. 2024) in female soccer players. In addition, Castagna et al. (2017) performed acute study where they compared different modes of training including SSG, running drills and long sprint ability and found that running drills produced more external load and blood lactate concentration compared to the SSG as well as RPE was higher.

Regardless of the fact that this study was conducted on males, a similar effect can be expected in females, indicating potential utilization of this training form as well. Abovementioned studies and our results were also confirmed by recent meta-analysis by Clemente et al. (2021) who examined SSG and running-based HIIT on physical performance of soccer players. Results of this meta-analytical study also showed that running-based HIIT group achieved favourable improvements in linear sprinting compared to the SSG group. Main point is that by applying these methods, linear as well as COD sprinting times can be enhanced further. The most notable percentage changes in our study were recorded in the 30-15IFT which were 7.26% in the HIIT group and 1.01% in the control group. These results were also supported by large effect size value in the HIIT group (d = -2.68). These results are not surprising given the fact of higher transferability of training stimuli into the testing performance. Changes in reactive agility tests were also significant, but the magnitude of improvements was small.

This can be seen in table 2. Smaller practically meaningful changes in all agility test can be explained by missing cognitive and/or reaction component during traditional pre-planned running-based HIIT runs.

Similar results were also recorded in the study by Arslan et al. (2020) who performed zig-zag agility test with ball. Their results show small to moderate effect size values in the HIIT group compared to the group that performed small-sided games. These differences were also statistically significant favorizing the SSG group. Despite the significant results obtained in all measures it can be noted that effect sizes are highest for tests that are with their specificity closer to the actual experimental input like 30-15IFT. This study has also limitation that should be noted.

Limitation lies in the fact that we had not involved active control group in terms of comparison of different protocols. The control group in our case consisted of players who performed regular technical-tactical training. Experimental group in addition to the regular technical-tactical training carried out running-based HIIT. It could be argued that one group did more training volume so they improved more but the main point of this study was to point out that simple and low-time consuming implementation of running-based HIIT into the regular training regime can enhance multiple physical characteristics in young female soccer players. Future research should focus on implementing various HIIT formats and their direct comparison from short-term and long-term perspective. Interesting application would be in real-life scenario with direct transfer into the practice.

Conclusions

In conclusion, this study shows that inclusion of simple and overall short duration of running-based HIIT into the training process can enhance linear sprint performance, intermittent fitness test as well as agility performance with higher practical meaning for activities of similar movement and physiological profile like 30-15IFT. When compared to the control group inclusion of HIIT COD protocol significantly improved 30-15IFT and 5-0-5 agility test.

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References

Arslan, E., Orer, G. E., & Clemente, F. M. (2020). Running-based high-intensity interval training vs. small-sided game training programs: Effects on the physical performance, psychophysiological responses and technical skills in young soccer players. Biology of Sport, 37(2), 165-173. https://doi.org/10.5114/biolsport.2020.94237

Azmi, K., & Kusnanik, N. W. (2018). Effect of exercise program speed, agility, and quickness (SAQ) in improving speed, agility, and acceleration. In Journal of Physics: Conference Series, 947(1), p. 012043. IOP Publishing.

Bakaľár I, Šimonek J, Kanásová J, Krčmárová B, Krčmár M. (2020) Multiple athletic performances, maturation, and Functional Movement Screen total and individual scores across different age categories in young soccer players. *J Exerc Rehabil.*, 16(5), 432-441. https://doi: 10.12965/jer.2040546.273.

Bangsbo, J., Iaia, F. M., & Krustrup, P. (2008). The Yo-Yo intermittent recovery test: A useful tool for evaluation of physical performance in intermittent sports. Journal of Sports Medicine and Physical Fitness, 48(2), 166-177. doi: 10.2165/00007256-200838010-00004

Barber, O. R., Thomas, C., Jones, P. A., McMahon, J. J., & Comfort, P. (2016). Reliability of the 505 change-of-direction test in netball players. International Journal of Sports Physiology and Performance, 11(3), 377-380. doi: 10.1123/ijspp.2015-0215

Bradley, P. S., DiMascio, M., Peart, D., Olsen, P., & Sheldon, B. (2010). High-intensity activity profiles of elite soccer players at different performance levels. Journal of Strength and Conditioning Research, 24(9), 2343-2351. doi: 10.1519/JSC.0b013e3181aeb1b3

Castagna, Carlo & Francini, Lorenzo & Póvoas, Susana & Dottavio, Stefano. (2017). Long Sprint Abilities in Soccer: Ball vs Running Drills. International Journal of Sports Physiology and Performance. 12. 1-22. doi:10.1123/ijspp.2016-0565.

Clemente, F. M., Ramirez-Campillo, R., Afonso, J., & Sarmento, H. (2021). Effects of small-sided games vs. running-based high-intensity interval training on physical performance in soccer players: A meta-analytical comparison. Frontiers in Physiology, 12, 642703. https://doi.org/10.3389/fphys.2021.642703

Cohen, J. (1992). A power primer. Psychological Bulletin, 112(1), 155-159. https://doi.org/10.1037/0033-2909.112.1.155

Čović, N., Jelešković, E., Alić, H., Rađo, I., Kafedžić, E., Sporiš, G., McMaster, D. T., & Milanović, Z. (2016). Reliability, validity and usefulness of 30-15 intermittent fitness test in female soccer players. Frontiers in Physiology, 7, 510. https://doi.org/10.3389/fphys.2016.00510

Ehnold, P., Gohritz, A., Lotzen, L., & Schlesinger, T. (2024). Soccer above all? Analysis of academic and vocational education among female soccer players in the German women's Bundesliga and 2nd women's Bundesliga. Frontiers in Sports and Active Living, 6, 1294803. https://doi.org/10.3389/fspor.2024.1294803

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behavior Research Methods, 39, 175-191.

Gabbett, T. J. (2016). The training-injury prevention paradox: Should athletes be training smarter and harder? British Journal of Sports Medicine, 50(5), 273-280. doi: 10.1136/bjsports-2015-095788

He, J., Liu, D., Wang, T., Xu, Q., & Zhao, X. (2024). Sex influences the extent of physical performance adaptations in response to small-sided games and running-based high-intensity interval training: A parallel study design involving men and women soccer players. Journal of Sports Science and Medicine, 23, 265-275. https://doi.org/10.52082/jssm.2024.265

Hewitt, A., Norton, K., & Lyons, K. (2014). Movement profiles of elite women soccer players during international matches and the effect of opposition's team ranking. Journal of Sports Science, 32, 1874-1880. doi: 10.1080/02640414.2014.898854

Choi, J.H., & Joo, CH. (2022). Match activity profile of professional female soccer players during a season. Journal of Exercise Rehabilitation, 18, 324-329. doi: 10.12965/jer.2244354.177

Impellizzeri, F. M., Rampinini, E., & Marcora, S. M. (2005). Physiological assessment of aerobic training in soccer. Journal of Sports Sciences, 23(6), 583-592. doi: 10.1080/02640410400021278

Matlák, J., Tihanyi, J., & Rácz, L. (2016). Relationship between reactive agility and change of direction speed in amateur soccer players. Journal of Strength and Conditioning Research 30, 1547-1552, doi: 10.1519/JSC.0000000000001262

Milanović, Z., Sporiš, G., & Weston, M. (2015). Effectiveness of high-intensity interval training (HIT) and continuous endurance training for VO2max improvements: A systematic review and meta-analysis of controlled trials. Sports Medicine, 45(10), 1469-1481.

Moir, G., Button, C., Glaister, M., & Stone, M. H. (2004). Influence of familiarization on the reliability of vertical jump and acceleration sprinting performance in physically active men. Journal of Strength and Conditioning Research, 18(2), 276-280. doi: 10.1519/R-13093.1

Mujika, I., & Padilla, S. (2000). Detraining: Loss of training-induced physiological and performance adaptations. Part I. Short term insufficient training stimulus. Sports Medicine, 30(2), 79-87. doi: 10.2165/00007256-200030020-00002

Nayıroğlu, S., Yılmaz, A. K., Silva, A. F., et al. (2022). Effects of small-sided games and running-based high-intensity interval training on body composition and physical fitness in under-19 female soccer

players. BMC Sports Science, Medicine and Rehabilitation, 14, 119. doi: 10.1186/s13102-022-00516-z

Oliver, J. L., & Meyers, R. W. (2009). Reliability and generality of measures of acceleration, planned agility, and reactive agility. International Journal of Sports Physiology and Performance, 4(3), 345-354. doi: 10.1123/ijspp.4.3.345

Pojskic, H., Åslin, E., Krolo, A., Jukic, I., Uljevic, O., Spasic, M. & Sekulic, D. (2018). Importance of reactive agility and change of direction speed in differentiating performance levels in junior soccer players: reliability and validity of newly developed soccer-specific tests. Frontiers of Physiology, 9:506, doi: 10.3389/fphys.2018.00506

Principe, V. A., Seixas-da-Silva, I. A., Gomes de Souza Vale, R., & de Alkmim Moreira Nunes, R. (2021). Tecnología GPS para controlar las demandas externas de las jugadoras de fútbol brasileñas de élite durante las competiciones (GPS technology to control of external demands of elite Brazilian female football players during competitions). Retos, *40,* 18–26. https://doi.org/10.47197/retos.v1i40.81943

Sekulic, D., Krolo, A., Spasic, M., Uljevic, O., & Peric, M. (2014). The development of a new stop'n'go reactive-agility test. Journal of Strength and Conditioning Research, 28(11), 3306-3312. https://doi.org/10.1519/JSC.0000000000000515

Stanković, M., Djordjevic, D., Katanic, B., Petrovic, A., Jelaska, I., Bjelica, D., & Mekic, A. (2023). Speed and agility training in female soccer players - A systematic review. Sport Mont Journal, 21(3), 117-122. https://doi.org/10.26773/smj.231018

Stanković, M., Trajković, N., Mačak, D., et al. (2024). Effects of linear and change of direction high-intensity interval training on physical performance of elite female soccer players. Biology of Sport, 41(4), 31-39. doi: 10.5114/biolsport.2024.134761

Stankovic, M., Djordjevic, D., Trajkovic, N., & Milanovic, Z. (2023). Effects of high-intensity interval training (hiit) on physical performance in female team sports: A Systematic review. Sports Medicine – Open, 9, https://doi.org/10.1186/s40798-023-00623-2

Yap, C. W., & Brown, L. E. (2000). Development of speed, agility, and quickness for the female soccer athlete. Strength & Conditioning Journal, 22(1), 9-12.

Authors' and translators' details:

Andrea Paprancová	apaprancova@ukf.sk	Author
Jaromír Šimonek	jsimonek@ukf.sk	Author
Ľubomír Paška	lpaska@ukf.sk	Translator
Monika Czaková	mczakova@ukf.sk	Author
Matúš Krčmár	mkrcmar@ukf.sk	Author