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Original Article

Impact of small-sided games and running-based high-intensity interval training on physical performance in female football players

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Abstract
We aimed to determine the effect of small-sided games (SSG) and running-based high-intensity interval training (HIIT) on the physical performance of female football players in the training process using global positioning system (GPS) systems and heart rate (HR)-monitoring devices. This study included 36 female elite football players (mean age: 15.69 ± 1.73 years, height: 164.33 ± 5.39 cm, and body weight: 57.44 ± 7.56 kg) who were randomly divided into two groups. The experimental period was an 8-week-long mesocycle, during which 12 sessions of SSG (4 vs. 4) and HIIT (15s - 15s with 95–105% V_{IFT}) were implemented. The physical test measurements included the 10-, 20-, and 30-m sprint tests; 30–15 intermittent fitness test (IFT); beep test; and the 5-0-5 agility test. The results revealed statistically significant changes between the pre- and post-tests in the 10-m test in the SSG group ($p = 0.002$; ES = 0.37), in the 30-m sprint in the SSG group ($p < 0.001$; ES = 0.52), in the 30–15 IFT in both experimental stimuli SSG ($p < 0.001$; ES = 1.00) and HIIT ($p < 0.001$; ES = 2.50), in the beep test in both experimental stimuli SSG ($p < 0.001$; ES = 1.40) and HIIT ($p < 0.001$; ES = 1.42), in the 5-0-5 agility test of the right leg ($p = 0.05$; ES = 0.55) and left leg ($p = 0.05$; ES = 0.39) in the SSG group. The study findings proved that the application of SSG and HIIT improved players' performance in endurance, speed, and change in direction speed, thereby providing fitness coaches with empirical evidence for improving the specific physical fitness of their players using the appropriate method of training.
Keywords: women's football, running-based high-intensity interval training, small-sided games, intermittent team sport, cardiovascular fitness

Introduction

Football is specified as a high-intensity intermittent team sport (Hoff et al., 2002; Nakamura et al., 2009), which is characterized by 1200 unpredictable changes in activity and requires intense activity, such as 30 to 40 sprints, tackles, jumps, and more than 700 turns from players every 3–5 s (Mohr et al., 2003; Bloomfield et al., 2007).

Women's football has seen a substantial increase in international competitions and professional and recreational leagues (Martínez-Lagunas et al., 2014). Female players have the opportunity to compete in professional settings, which means an increase in their performance expectations and the need for scientific research (Martínez-Lagunas et al., 2014). Knowing the physical demands of a match and monitoring external and internal loads during training sessions and matches are imperative to enhancing performance. This is related to the use of technologies such as global positioning system (GPS) devices and heart rate (HR) monitoring systems. These devices are commonly used in elite sports to monitor the external and internal loads of players to evaluate their physiological and movement demands (Cunniffe et al., 2009). In a match, a large part consists of walking (<7.1 km/h) and jogging (7.2–14.4 km/h) and moderate intensity activities (14.4–19.8 km/h), less values players cover in very high intensity zone (19.8–25.2 km/h) and sprint (>25 km/h) (Hewitt et al., 2014; Mara et al., 2017). Studies on the use of GPS technology have found that elite and sub-elite female football players in a match covered a total distance of approximately 8–11 km (Andersson et al., 2010; Bradley et al., 2014; Hewitt et al., 2014; Trewin et al., 2018).

Regardless of sex, football players need to have great aerobic and anaerobic capacity to be successful (Karakoç et al., 2012; Hazir et al., 2018). Recently, coaches have used different training forms to improve players´ physical capacity, such as aerobic and speed endurance and changes in direction speed, which are required for matches (Sarmento et al., 2018). Currently, training forms with short time requirements, high-intensity interval training (HIIT), and small-sided games (SSG) are very popular and effective (Wong et al., 2010). High-intensity interval training (HIIT) is an intermittent exercise with short bouts of high-intensity effort and recovery periods that can improve maximal aerobic capacity, VO2max, and anaerobic metabolism (Dellal et al., 2010). Maximum oxygen consumption (VO2max) with HIIT (>85% HRmax) can be improved by 5–11% (Iaia et al., 2009). In their study, Sperlich et al. (2011) used HIIT three times a week for 5-weeks mesocycle with intervals at 90–95% HRmax, and players VO2max improved by 7% from 55.1 ± 4.9 to 58.9 ± 4.7

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$mL\cdot min^{-1}\cdot kg^{-1}$. Similarly, Arslan et al. (2020) in their study used HIIT 12–20 min of continuous runs at intensities (90–95%) related to the velocity (V_{IFT}) obtained in the 30–15 intermittent fitness test (IFT) during 5 weeks and VO2max improved by 4.5% from 46.8 ± 0.6 to 48.9 ± 0.9 $mL\cdot min^{-1}\cdot kg^{-1}$. Abovementioned studies were comprised of male soccer players and there are limited sources regarding females. Hovewer, Stankovic et al. (2023) performed a systematic review that examined effect of HIIT training on physical performance in female team sports. To this date they found 13 studies overall that examined this type of training from which 3 were realted to soccer (Rowan et al., 2012; Wright et al., 2016; Arazi et al., 2017) and 2 to futsal. Overall findings suggest improvements in VO2max, RSA, COD and explosive strength. Detailed analysis of selected outcomes in soccer studies shows that after different HIIT training variation VO2max, 20m sprint time, Vift and YYIR1 (YoYo intermitent Recovery Tetst level 1) were significantly improved. Similar findings were also found in futsal studies but they used more intensive training variation more relates to sprinting and COD performance. Based of the abovementioned studies it seems that HIIT training of different variations may have significant effect on phzsical performance of female soccer players.

As previously mentioned, small-sided games (SSGs) are another popular form of training for improving cardiovascular fitness (Clemente et al., 2014). For instance Clemente et al. (2021) in their meta-analytical study compared small-sided games versus running based high-intensity interval training on repeated sprint ability. Their study design was performed irrespective of age, sex and competitive level. Authors found no significant differences in performance outcomes between these two conditions. Hovewer, in more than 50% of included studies more performance improvements were seen after HIIT training variation compared to the SSG. SSGs are comparable to match conditions, have been used in football for years and have an impact on physical capacity, technical skills, and tactical awareness (Dellal et al., 2012). The intensity of SSG can be influenced by several variables, such as pitch size, number of players, rules, presence of goalkeepers, duration of exercise, and coach encouragement (Mallo and Navarro, 2008; Hill-Haas et al., 2010; Rampinini et al., 2007, Paľo et al., 2023).). In their study, Hill-Haas et al. (2009) used a 7-week mesocycle in pre-season comprising 3 × 6 min and 6 × 13 min of SSG with interval (>80% HRmax) with 1–2 min of rest between bouts, and VO2max increased by 17.1%. Arslan et al. (2020) in their study used SSG consisting of two 5–9 min of 2-a-side with 2-min passive rest periods, and VO2max improved by 3.4%. In their research Sannicandro et al (2020) found out that the greatest distance covered at high intensity was in the 5vs5 format ($p<0.0005$), which was also characterized by the greatest amount of high-power running (>20W/kg; $p<0.01$), and maximum-power running ($p<0.0005$). Significantly more acceleration events were detected in the 5vs5 format ($p<0.0005$), whereas the number of decelerations was significantly greater in the 6vs6 compared with the 7vs7 format ($p<0.05$).

To our knowledge, and based on the abovementioned studies and novel systematic review which is up to date the adaptation effects of the two different training methods (SSG and HIIT) on the physical performance of female soccer players are very limited and more research in this population is required to draw clear conclusions. Hovewer, we could see that physical adaptation and training reponses of females to HIIT and SSG are similar to male soccer players, and some studies showed that some performance metrics may be more affected by one or another training method. Therefore, we hypothesized that HIIT training is more effective to develop aerobic endurance and speed performance and that SSG training is more effective for improving change of direction speed.

Material & methods

Participants

Thirty-six female football players participated in this study. Before the experiment, players were randomly divided into two groups: HIIT (n=18, mean decimal age: 15.69 ± 1.73 years, height: 164.33 ± 5.39 cm, body weight: 57.44 ± 7.56 kg) and SSG (n=18, mean decimal age: 20.39 ± 5.22 years, height: 165.17 ± 5.25 cm, body weight: 61.78 ± 8.41 kg). All the players were recruited from an amateur football team, the GFC Regional Academy, which plays in the top Slovak Women's League. Goalkeepers were excluded from the study because of differences in the training load and specificity of the training means as compared with those of field players. All players involved in the study had to complete at least 80% of the training process. All players voluntarily participated in the experiment with a detailed explanation of the objectives and risks associated with the experimental program. The written informed consent form and the study were approved by the University Ethics Committee. 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 study. The study was approved by the GFC Regional Academy, the local research ethics committee, and the University Ethics Committee (registration number: UKF-2020/1355-1:191013) and complied with the Declaration of Helsinki.

Procedures

Field Testing In the 10-, 20- and 30-m sprints, the time was recorded using a Witty dual-beam wireless training timer (Microgate, Bolzano, Italy). The participants started with the toe of the preferred foot positioned 0.3 m behind the starting line. When the players were ready, they sprinted as fast as possible until they crossed the finish line. The players performed two trials, and the best time was recorded. All measurements were performed under similar standardized conditions on the artificial pitch. The reliability of this test has already been investigated at 10 m (ICC: 0.93), 20 m (ICC: 0.89–0.95), and 30 m (ICC: 0.93) (Moir et al., 2004).

The 30–15 IFT comprised 30-s shuttle runs interspersed with 15-s walking recovery periods. The test starting speed was 8 km/h (i.e., first 30-s shuttle run), and this speed increased by 0.5 km/h for every 30-s stage thereafter. Therefore, the running speed at stages 1, 2, and 3 is 8 km/h, 8.5 km/h, and 9 km/h, respectively. Athletes were required to run back and forth between the two lines set 40 m apart at a speed governed by an audio "beep." As the individual progressed through the levels, the time between beeps decreased, giving the individual less time to complete each shuttle, thereby increasing the speed and intensity of the test. The two 3-m zones in the middle of the testing area (6 m in total) exist so that the athletes can gauge the required running speed and therefore adjust their speed accordingly (i.e., speed-up or slow-down). The two 3-m end zones/turning lines also helped guide the athletes to adjust/maintain their speed. During the 15-s recovery period, athletes were required to walk in a forward direction towards the closest 3-m zone; this zone is where they would have started the next running stage. Athletes had to reach the next 3-m zone, either the middle one or the end one, on a consistent basis. Failure to reach the next 3-m zone on three consecutive occasions resulted in elimination from the test. The reliability of this test has already been investigated (ICC: 0.91) (Čovič et al., 2016).

The beep test involved continuous running between two lines 20 m apart relative to the recorded beeps. The participants stood behind one of the lines facing the second line and began running as instructed by the recordings. The players continued to run between the two lines and turned when signaled by recorded beeps. After approximately 1 min, the sound indicated an increase in speed, the beeps were closer together, and the players had to run faster. This process was continued for each minute (level). If the line was not reached before the beep sounds, players got a warning and had to continue to run to the line, then turned and tried to catch up with the pace within two more "beeps." The players received a warning the first time they failed to reach the line (within 2 m) and were eliminated after the second warning. The reliability of this test has already been investigated (ICC: 0.96) (Holme et al., 2011). For the 5-0-5 agility test, a Witty dual-beam wireless training timer (Microgate, Bolzano, Italy) was employed, and the athlete ran from the 15-m marker towards the line and through the 5 m markers, turned on the line, and ran back through the 5-m markers. Time was recorded from the moment the athlete first crossed the 5-m marker and stopped when the participant crossed back through the markers. The better of the two trials was recorded. Turning ability was measured for both legs. The reliability of this test has already been investigated (ICC: 0.96) (Barber et al., 2015).

Training design

The training program included eight microcycles, each lasting 7 days. The first and last microcycles included pre-testing and post-testing sessions. After the testing, the players underwent technical-tactical training. From the second to the seventh weeks, each microcycle consisted of three training sessions. On Mondays and Wednesdays, players completed technical-tactical training with the application of HIIT and SSG experimental stimuli during the last 20 min. Technical-tactical training was employed on Fridays, with rest on Tuesdays and Thursdays. All players received the same training routines, except for the HIIT and SSG sections. All training sessions were performed on the artificial turf (Table 1).

Table 1 Experimental design

Experiment	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1 Week	5-0-5 30-15IFT	Free day	10,20,30m Beep test	Free day	Tec/Tac	Free day	Free day
2 Week	SSG – 4vs.4 HIIT-15s-15s – 95% VIFT	Free day	SSG – 4vs.4 HIIT-15s-15s – 95% VIFT	Free day	Tec/Tac	Free day	Free day
3 Week	SSG – 4vs.4 HIIT-15s-15s – 95% VIFT	Free day	SSG – 4vs.4 HIIT-15s-15s – 95% VIFT	Free day	Tec/Tac	Free day	Friendly match
4 Week	SSG – 4vs.4 HIIT-15s-15s – 100 % VIFT	Free day	SSG – 4vs.4 HIIT-15s-15s – 100 % VIFT	Free day	Tec/Tac	Free day	Free day
5 Week	Friendly match HIIT- 15s-15s – 100 % VIFT	Free day	SSG - 4vs.4 HIIT-15s-15s – 100 % VIFT	Free day	Tec/Tac	Friendly match	Free day
6 Week	SSG - 4vs.4 HIIT-15s-15s – 105 % VIFT	Free day	SSG - 4vs.4 HIIT-15s-15s – 105 % VIFT	Free day	Tec/Tac	Free day	Friendly match
7 Week	SSG - 4vs.4 HIIT-15s-15s – 105% VIFT	Free day	SSG - 4vs.4 HIIT-15s-15s – 105% VIFT	Free day	Tec/Tac	Free day	Free day
8 Week	5-0-5 30-15IFT	Free day	10,20,30m Beep test	Free day	Tec/Tac	Free day	Free day

*Tec/Tac – technical-tactical training; SSG – small-sided games; HIIT – running based high-intensity interval training, VIFT - velocity reached in 30-15 intermittent fitness test *SSGs*

The training stimuli were performed with 4 vs. 4 players in a 35 × 25 m pitch area. Game intensity consisted of six sets of 2 min of activity, which were interspersed with 2 min of rest (Table 2). All the SSGs were played without goalkeepers or on artificial grass. The intensity of the game was controlled by two coaches to encourage the players. The balls were evenly distributed around the pitch area to ensure continuity during the game. The players' task was to finish the ball with a small goal, thereby scoring points for their team. A rule that all players had to be halfway down the field was used to increase intensity during weeks 3 and 4. A rule with a maximum of three ball contacts was used during weeks 5 and 6.

Table 2 Characteristics of the SSGs training

SSG	number of players	pitch area			intensity		
	(n = 18)	width (m)	length (m)	m2	Bout duration (min.)	Duration of recovery (min.)	Number of bouts
	4:04	25	35	875	2	2	6

Running-based HIIT

Players covered a predetermined distance over 60 m straight-line runs in 15-s intervals. After each interval, players passively rested for 15 s and then began the next 15-s interval but ran in the opposite direction. This task was repeated for three bouts of 4 min each, with 3 min of passive rest between bouts (Table 3). The intensity during the first two weeks was set to 95% V_{IFT} (55–73 m), followed by 100% V_{IFT} (58–77 m) in weeks 3 and 4, and 105% V_{IFT} (61–80 m) in the last two weeks. The individual intensities of the runs were selected based on the results of the 30-15 IFT.

Table 3 Characteristics of HIIT training

HIIT	number of players	intensity 15s/15s		
	(n = 18)	Bout duration (min.)	Duration of recovery (min.)	Number of bouts
		4	3	3

External and internal load

The external load was measured during each training session, and the players wore a global positioning system (GPS) Titan 2 Sensor sampling at 10 Hz. Each player wore a vest and a GPS device 15-min before the training session. For total weekly volume and volume during SSGs and running-based HIIT,the following parameters were selected: total distance (m), sprint count, sprint average distance (m), jogging (7.2–14.4 km/h) (m), moderate intensity zone (14.4–19.8 km/h) (m), very high intensity zone (19.8–25.2 km/h) (m), acceleration (>3 m/s²), deceleration (>-3 m/s²). The internal load was measured during each training session using HR monitors (Polar H10) and analyzed using Polar Team software. The maximum HR was obtained from the 30–15 IFT.

Statistical analysis

The obtained data were processed using basic mathematical and statistical methods (arithmetic mean, standard deviation, median, and range). The normality of the data distribution was calculated using the Shapiro–Wilk test. For assessing the statistical significance from pre- to post-test, a parametric paired test (t-test) was used. A two-sample t-test was used to assess the statistical significance between group measurements. Data are presented as the mean ± SD (standard deviation). 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; and >0.8, large (Cohen, 1992). All data analyses were performed using Microsoft Excel.

Results

Table 4 summarizes the experimental results, which assume that between the pre- and post- tests, statistically significant changes were observed in the 10-m sprint test in the SSG group (p = 0.002; ES = 0.37), the 30-meter sprint in the SSG group (p < 0.001; ES = 0.52), 30–15 IFT in both experimental stimulus SSG (p < 0.001; ES = 1.00) and HIIT (p < 0.001; ES = 2.50), beep test in both experimental stimulus SSG (p < 0.001; ES = 1.40) and HIIT (p < 0.001; ES = 1.42), in 5-0-5 agility test of the right leg (p = 0.05; ES = 0.55) and left leg (p = 0.05; ES = 0.39) in the SSG group.

Table 4 Performance characteristics across the group after pre- and post-training measurements (mean ± SD)

Parameter/Group	SSG		*d*	HIIT		*d*
	Pre	Post		Pre	Post	
10m	2,01 ± 0,09	1,98 ± 0,07**	0,37	2,01 ± 0,07	2,01 ± 0,07	0,00
20m	3,50 ± 0,14	3,47 ± 0,11	0,23	3,57 ± 0,17	3,56 ± 0,15	0,06
30m	4,96 ± 0,20	4,86 ± 0,18**	0,52	5,06 ± 0,22	5,02 ± 0,20	0,19
30-15IFT	16,0 ± 1,00	17,0 ± 1,00**	1,00	15,5 ± 1,00	18,0 ± 1,00**	2,50
beep test	1136 ± 164	1393 ± 199**	1,40	1148 ± 143	1493 ± 240**	1,42
5-0-5 R	2,54 ± 0,09	2,49 ± 0,09*	0,55	2,56 ± 0,12	2,54 ± 0,10	0,18
5-0-5 L	2,57 ± 0,11	2,53 ± 0,09*	0,39	2,57 ± 0,12	2,57 ± 0,11	0,00

*0.05 pre- to post- training; **0.01 pre- to post- training; SD = standard deviation; d - cohen´s, effect size

The selected external and internal load characteristics from the experimental stimuli and the 6-week mesocycle are shown in Tables 5 and 6, respectively. The weekly accumulated training loads for both groups during the entire training session were similar, as shown in Tables 7 and 8.

Table 5 External and internal load during SSG

SSG (4:4)	1. week		2. week		3. week		4. week		5. week		6. week	
	MON	WED	MON	WED	MON	WED	MON	WED	MON	WED	MON	WED
jogging (7.2-14.4 km/hr) (m)	722±165	555±162	319±71	395±47	420±654	440±184	411±180	483±144	462±103	349±135	307±80	440±95
moderate intensity zone (14.4-19.8 km/hr) (m)	117±30	61±37	42±14	33±20	50±30	48±36	51±44	78±25	70±23	44±32	45±28	53±40
very high intensity zone (19.8-25.2 km/hr) (m)	10±2	7±0,5	9±2	8±0	6±0	8±0	13±8	16±5	14±6	4±5	10±3	9±4
total distance (m)	1860±390	1250±320	1050±142	1010±220	990±201	1300±248	1000±330	1235±218	1154±191	1000±218	900±116	1070±210
sprint count	4	0	0	0	0	0	0	0	0	0	1	0
sprint average distance (m)	103	0	0	0	0	0	0	0	0	0	57	0
accelerations >= 3m/s²	6±3	2±3	2±1	2±2	1±1	4±3	1±2	1±1	3±3	2±1	3±2	2±2
decellerations <= -3m/s²	8±3	5±3	2±1	3±2	2±2	5±4	2±2	3±2	6±4	2±1	2±1	1±2
heart rate (%)	89±1	91±2	91±1	92±2	90±1	92±2	93±1	94±1	91±2	92±1	92±2	91±3

Table 6 External and internal load during HIIT

HIIT (15s/15s)	1. week		2. week		3. week		4. week		5. week		6. week	
	MON	WED	MON	WED	MON	WED	MON	WED	MON	WED	MON	WED
jogging (7.2-14.4 km/hr) (m)	571±138	275±43	270±55	336±96	410±183	472±212	628±271	221±43	403±166	408±120	427±103	417±130
moderate intensity zone (14.4-19.8 km/hr) (m)	954±221	992±140	945±157	900±204	910±331	967±215	806±321	798±123	927±166	1068±123	1144±180	1105±176
very high intensity zone (19.8-25.2 km/hr) (m)	191±124	181±104	166±156	126±109	120±117	154±112	116±108	201±262	158±129	305±264	119±162	284±209
total distance (m)	1558±282	1566±144	1566±121	1500±263	1600±248	1685±165	1620±162	1397±140	1622±199	1846±192	1781±191	1872±185
sprint count	4	1	0	1	0	1	2	0	0	1	0	0
sprint average distance (m)	194	31	0	51	0	18	41	0	0	45	0	0
accelerations >= 3m/s²	14±9	8±6	6±5	8±5	6±6	10±8	5±4	12±7	10±4	5±3	4±4	6±5
decellerations <= -3m/s²	2±2	1±0	0±0	1±2	1±0	1±0	0±0	1±1	0±0	0±0	1±0	0±0
heart rate (%)	93±3	91±2	91±3	92±3	91±2	93±2	92±3	93±2	92±2	92±2	93±1	93±2

Table 7 External and internal load during the entire training sessions SSG

Training program - SSG	1. week		2. week		3. week		4. week		5. week		6. week	
	MON	WED	MON	WED	MON	WED	MON	WED	MON	WED	MON	WED
jogging (7.2-14.4 km/hr) (m)	608±102	1330±113	1986±163	2854±411	1318±736	3484±315	2664±687	2810±421	3152±370	2496±162	1732±150	2460±270
moderate intensity zone (14.4-19.8 km/hr) (m)	978±33	1044±185	1184±140	1256±278	944±679	1666±260	1130±417	1134±264	1214±322	1282±182	1262±248	1240±157
very high intensity zone (19.8-25.2 km/hr) (m)	262±115	224±13	176±232	142±55	114±147	238±153	102±71	230±276	172±181	180±193	62±53	132±80
total distance (m)	2522±556	4962±198	4264±338	4838±411	2104±379	5908±660	5370±421	5398±419	5772±272	5028±166	2186±155	4751±540
sprint count	3	0	0	2	8	0	1	0	0	3	1	0
sprint average distance (m)	155	0	0	76	912	0	23	0	0	127	57	0
accelerations >= 3m/s²	7±4	17±12	9±9	15±7	7±6	16±12	9±7	14±11	18±6	4±3	6±6	8±4
decellerations <= -3m/s²	9±4	4±2	5±4	3±3	5±7	9±5	8±4	7±4	6±7	2±3	2±1	4±2
heart rate (%)	82±4	80±3	83±3	78±4	79±2	82±3	85±4	86±2	85±2	83±3	83±3	83±2

Table 8 External and internal load during the entire training sessions HIIT

Training program - HIIT	1. week		2. week		3. week		4. week		5. week		6. week	
	MON	WED	MON	WED	MON	WED	MON	WED	MON	WED	MON	WED
jogging (7.2-14.4 km/hr) (m)	534±185	1278±167	1886±198	2418±857	1258±736	3340±540	2428±147	2668±314	2428±147	2668±314	1538±190	2243±427
moderate intensity zone (14.4-19.8 km/hr) (m)	930±109	1036±132	1188±176	974±562	880±385	1468±465	1128±433	1016±187	1128±433	1016±187	1134±188	1210±321
very high intensity zone (19.8-25.2 km/hr) (m)	120±115	68±8	172±118	92±162	60±85	136±150	82±59	190±300	82±59	190±300	44±61	93±46
total distance (m)	2458±222	4894±241	3954±451	4550±780	1978±798	5982±396	5118±742	5252±302	5118±742	5252±302	1972±199	4526±680
sprint count	4	1	0	1	0	1	2	0	1	1	0	0
sprint average distance (m)	194	31	0	51	0	18	41	0	19	45	0	0
accelerations >= 3m/s²	5±4	8±5	9±8	6±6	5±7	7±6	7±6	11±10	7±6	11±10	3±3	6±3
decellerations <= -3m/s²	7±3	3±1	4±3	0±1	1±0	9±4	6±4	6±4	6±4	6±4	0±1	3±2
heart rate (%)	83±3	82±1	80±4	82±2	81±2	83±3	84±2	85±2	84±2	85±2	82±3	82±2

Discussion

The present study aimed to investigate the effect of a 6-week running-based HIIT (3 × 4 min of 95–105%) vs. 6-week SSGs (6 × 2 min 4 vs. 4) on aerobic endurance and maximal speed in female football players using the 10 and 20 m sprints (acceleration speed), 30 m sprint (maximum speed), 30–15 IFT (aerobic endurance test), continuous beep test (aerobic endurance test), and 5-0-5 agility test (running agility test). As indicated by our study findings, after the application of experimental factors, we achieved statistically significant improvements in the 10 and 30 m sprint test in the SSG group, in the 30–15 IFT test and the beep test in both groups, and in the 5-0-5 agility test in the SSG group. No statistically significant improvements were observed in the 20-m sprint test in either group.

Statistically significant changes between pre- and post-test results in the 10-m sprint test were observed only in the SSG group ($p = 0.002$; ES = 0.37; small effect). Players in the SSG group improved their speed performance by 1.56%. No statistically significant changes were observed in the HIIT group ($p = 0.56$; ES = 0.00; very small effect). Players individually improved by 0.24%. Randziminski et al. (2013), in their study, found that the use of SSG and HIIT did not improve speed performance. In addition, the SSG group showed a deterioration from 2.05 ± 0.12 to 2.07 ± 0.12 s, and no changes were observed in the HIIT group (2.02 ± 0.10 s). A similar study by Faude et al. (2014) that included 19 German football players who underwent 4 weeks of SSG and HIIT showed no statistically significant improvement in the 10 m sprint test. Moreover, the SSG group showed deterioration in results from 1.73 ± 0.07 s to 1.74 ± 0.06 s, and no changes were observed in the HIIT group (1.73 ± 0.06 s). Conversely, a comparative study of SSG and HIIT over a period of 5 weeks by Arslan et al. (2020) demonstrated statistically significant improvements in young soccer players in both groups. Players in the SSG and HIIT groups improved their performance by 5.9% (ES = 1.77; large effect), and 5% (ES = 1.75; large effect), respectively. Moreover, Nayıroğlu et al. (2022) elucidated improvements in female players in both groups during 8 weeks of SSG and HIIT. Players showed improved performance from 2.02 ± 0.08 s to 2.01 ± 0.08 s and from 2.15 ± 0.09 s to 2.08 ± 0.12 s in the SSG and HIIT groups, respectively. More significant improvements were achieved in the HIIT group. The use of an experimental stimulus in our study did not have a significant effect on improving acceleration speed, and we achieved a greater effect in the SSG group, which may also be owing to the accelerations and decelerations that occur in the SSG more often than in the HIIT used in our study. On comparing the pre- and post-test results of individual players, 15 and 12 players in the SSG and HIIT groups, respectively, improved their performance (n =18 in each group).

No statistically significant changes were observed in the 20-m sprint test in both groups. In the SSG group, players improved only by 0.66% ($p = 0.06$; ES = 0.23, small effect). In the HIIT group, players improved by 0.14% ($p = 0.65$, ES = 0.06, very small effect). Zeng et al. (2021) investigated the effects of SSG and HIIT for 4 weeks in female basketball players. In the SSG group, female players improved by 1.1% from 3.77 ± 0.21 s to 3.73 ± 0.18 s (ES = 0.2), whereas in the HIIT group, the performance worsened by 1.3% from 3.74 ± 0.18 s to 3.79 ± 0.1 s (ES = 0.2). Consistent with our results, no significant improvement in acceleration speed was achieved. However, the study by Arslan et al. (2022), which used SSG and HIIT in young basketball players, demonstrated statistically significant improvement in both groups, from 3.47 ± 0.24 s to 3.36 ± 0.22 s (ES = 0.48) and from 3.43 ± 0.21 s to 3.30 ± 0.19 s (ES = 0.65) in the SSG and HIIT groups, respectively. In addition, Jurišić et al. (2020) investigated the adaptation effect of SSG and HIIT for 8 weeks in young female handball players. Players in both groups showed improved performance; SSG and HIIT groups improved by 1.68% and 1.94%, respectively. A similar study by Stojiljković et al. (2019), which investigated the effect of SSG and HIIT over 8 weeks in young soccer players, elucidated an improvement by 1.2% and 4.2% in the SSG and HIIT groups, respectively. Similarly, Arslan et al. (2020) reported statistically significant improvements in both groups, from 3.79 ± 0.23 s to 3.51 ± 0.16 s (7.4%) and from 3.55 ± 0.16 s to 3.33 ± 0.12 s (6.2%) in the SSG and

HIIT groups, respectively. Several studies have applied SSG and HIIT to young male and female players and, therefore, may have achieved a higher adaptation effect than in studies that dealt with adult female players. From a biological perspective, players in the lower categories have a greater influence on speed abilities than adult players. On comparing the individual pre- and post-test results of 18 players, 12 players improved equally in both groups.

Comparison of the pre- and post-test results in the 30-m maximum speed test revealed statistically significant changes only in the SSG group (p = <0.001; ES = 0.52; medium effect), and players improved by 1.92%. No statistically significant changes were observed in the HIIT group (p = 0.14; ES = 0.19; small effect), and players improved by 0.68%. In contrast, Nayıroğlu et al. (2022) during eight weeks of SSG (2:2; 3:3) and HIIT achieved a statistically significant improvement in female players in the HIIT group. The performance of female players in the SSG group deteriorated by 0.6% from 4.97 ± 0.19 s to 5.00 ± 0.17 s, whereas the performance of players in the HIIT group improved by 1.3% from 5.27 ± 0.23 s to 5.20 ± 0.18 s. Arslan et al. (2020) achieved statistically significant improvements among young soccer players (14.2 ± 0.5 years) in both SSG and HIIT groups; players in SSG and HIIT groups improved by 6.6% and 6.8%, respectively. Faude et al. (2014) used SSG (3:3; 4:4) with young soccer players and did not achieve a statistically significant improvement, whereas players in the HIIT group improved by 0.7%. Domčeková et al. (2023) investigated the impact of different forms of HIIT-linear running, including running with changes in direction and a combination of these two forms, on young soccer players, similar to that used in our study. Their study results demonstrated that the best improvement of 1.9% can be achieved by using a combination of both linear and running with change of direction, because many accelerations and decelerations will be present while running with changes in direction, and during linear running, players are able to achieve speed (> 25 km/h). Comparing the individual player outcomes between the pre- and post-tests, 16 and 13 players showed performance improvement in the SSG and HIIT groups, respectively (n = 18 in each group).

When comparing the pre- and post-test results of the aerobic endurance, 30–15 IFT, statistically significant changes were observed in both the SSG (p < 0.001; ES = 1.00; large effect) and HIIT groups (p < 0.001; ES = 2.50; large effect). Players in the SSG group improved their performance by 10.96% after the experimental factor, and players in the HIIT group improved by 13.92%. Similarly, in a study by Nayıroğlu et al. (2022), players improved their endurance capabilities using SSG and HIIT by 8.5% and 10.7%, respectively. Furthermore, Zeng et al. (2021) showed that the impact of SSG and HIIT led to improved aerobic endurance among female basketball players with 4.1% in the SSG group and 4.2% in the HIIT group. Furthermore, Jurišić et al. (2020) observed that both experimental stimuli, SSG and HIIT, had a significant impact on improving endurance capabilities in young handball players, 17.6% improvement in the SSG group and 28.4% improvement in the HIIT group. To date, all existing studies demonstrate that a greater adaptive effect was achieved with HIIT in both male and female players. This could be attributed to the individualization and definition of the exact distance players had to run, as demonstrated by the volume recorded during the HIIT (Table 6). Domčeková et al. (2023) showed that using linear runs, HIIT led to a 3.7% improvement in players, whereas the combination of linear runs and changes in direction improved player performance by up to 7.5%. Regarding individual performance on the pre- and post-tests in the SSG and HIIT groupsall players showed improvements, with one player showing the highest improvement of up to 25.81%.

In the continuous uninterrupted beep test, statistically significant changes were observed in both the SSG (p < 0.001; ES = 1.40; large effect) and HIIT (p < 0.001; ES = 1.42; large effect) groups. Following the execution of the experimental program, an improvement of 23.42% and 32.05% was observed in the SSG and HIIT groups, respectively. Moreover, we calculated VO2max values, and similar statistically significant changes were observed in both SSG (p < 0.001; ES = 1.71; large effect) and HIIT (p < 0.001; ES = 1.47; large effect) groups. Players improved by 10.76% after the execution of the experimental program SSG and by 10.78% after the execution of the experimental HIIT. In a study by Arslan et al. (2020), young football players experienced an increase in VO2max because of SSG and HIIT, with a 3.3% increase in the SSG group and a 4.3% increase in the HIIT group. Similarly, in a study by Soylu et al. (2021), athletes in sports games such as football, basketball, and handball who had undergone a similar training program of less than three training sessions per week over the past 2 years using HIIT for 8 weeks improved their maximum oxygen consumption by 9.2%. Individual improvements were also achieved in both groups, with the greatest improvement in one of the player reaching up to 53.70%.

When comparing the pre- and post-test results in the 5-0-5 agility test for the right lower limb, statistically significant changes were observed only in the SSG group (p = 0.05; ES = 0.55; moderate effect size). After performing the experimental program SSG, players showed a percentage-wise improvement of 1.73%. No statistically significant changes were observed in the HIIT group (p = 0.11; ES = 0.18; very small effect), with players improving by only 0.80% after performing the experimental program HIIT. Moreover, only the SSG group showed statistically significant changes in the left lower limb test (p = 0.05; ES = 0.39; small effect), with a 1.26% improvement after performing the experimental program SSG. The HIIT group showed no statistically significant changes (p = 0.69; ES = 0.00; very small effect), and players improved by only 0.20%. Nayıroğlu et al. (2022) analyzed the running agility using the 5-0-5 test, where players chose their dominant lower limb, and found that SSG had a greater adaptation effect on players than HIIT with linear running. During SSG, players operate in a confined space, leading to numerous accelerations and decelerations, which may explain why the players in our study also improved and achieved a greater adaptation effect in the SSG group. Domčeková et al. (2023) showed that using HIIT with linear running did not yield statistically significant changes in either the right or left lower limb, with players improving by 1.8% in the left lower limb and 1.4% in the right. However, using a directional change running form resulted in a significant 4.6% improvement in the left lower limb. Regarding individual improvements in the SSG group (right), 13 players improved their performance, 4 worsened, and 1 showed no change. In the left lower limb test, 14 players improved, 4 worsened, and none showed any change. In the HIIT group (right), 12 players improved, 4 worsened, and 2 showed no change. In the left lower limb test, only 10 players improved, 5 worsened, and 3 showed no change.

Our study had the following limitations: the limited number of GPS and HR-monitoring devices, the limited number of devices for detecting external and internal loads, and a few training sessions per week (players participated only in three training sessions per week and only four friendly matches during 8-weeks).

Conclusions

Based on the results of our measurements and in accordance with the works by Nagy et al. (2020) we can recommend the coaches to integrate into the systematic training process the small-sided games with the longer load intervals and with shorter rest intervals. The reason is that these place demands on the cardiovascular system of the players and they are similar to the competitive match conditions. Optimization and intensification of the training load can be adjusted also by load intervals and rest intervals. It is strongly recommended to select SSG in a ratio of 1:1 and 1: 0.5 (LI:RI). It will help the players to increase the level of their skills by specific means. In our study comparing the effects of a 6-week running-based High-Intensity Interval Training (HIIT) and Small-Sided Games (SSGs) on female football players, both training methods exhibited specific advantages and limitations. The SSG group showed statistically significant improvements in the 10 and 30 m sprints, the 30–15 IFT, the continuous beep test, and the 5-0-5 agility test. However, no significant changes were observed in the 20 m sprint for either group. Moreover, the SSG group exhibited greater improvement in the 5-0-5 agility test, indicating its potential for enhancing running agility. In terms of aerobic endurance, both groups showed significant improvements in the 30–15 IFT and continuous beep test, with the HIIT group achieving slightly higher gains. This suggests that HIIT might have a greater impact on aerobic endurance.

In conclusion, 6 weeks of HIIT and SSG training can lead to relevant adaptations in aerobic endurance and maximal speed. Our results showed that HIIT had a better adaptation effect on aerobic endurance; however, in both groups, the players improved their physical performance. Similarly, SSG training had a better adaptation effect on maximal speed; however, players showed improved physical performance in both groups.

Conflict of interests

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Ethics statement

The study involving humans was approved by the Constantine the Philosopher University Ethics Committee with code. The study was conducted in accordance with the local legislation and institutional requirements. The participants provided their written consent to participate in this study.

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