THE EFFECT OF MAXIMAL AEROBIC SPEED TRAINING COMBINED WITH SMALL-SIDED GAMES ON PERFORMANCE PARAMETERS IN SOCCER

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Abstract:

The purpose of this research was to compare the effects of maximal aerobic speed (MAS) training, small-sided games (SSG) training, and combined training (CT) on sprint, agility, lactate accumulation, repeated sprint, aerobic, and anaerobic endurance performances. Thirty under-16 male players participated in a 6-week randomized training study. Pre- and post-training all players completed a test battery involving body composition (body height and Dual Energy X-Ray Absorptiometry-DEXA), sprint tests (10 m, 20 m, and 30 m), Yo-Yo 1 test, Arrowhead agility test, blood lactate test, and Yo-Yo 2 test. A global positioning system (GPS) was used for monitoring. After the pre-tests, the players were randomly assigned to three groups as MAS, SSG, and CT. Mixed two-way ANOVA was used to compare the pre-test and post-test performance of the three groups. While the CT group had higher changes in body composition, repeated sprint, aerobic, and anaerobic endurance parameters compared to the MAS training group ($p<.05$), the SSG training group had similar changes as the CT group ($p>.05$). In conclusion, coaches and sports scientists are advised to choose CT for more efficient training, considering the differences between the MAS training and CT methods.

Key words: *small-sided games, maximal aerobic speed, game-based training, young male players, football*

Introduction

Young soccer players run a total distance of 6-10 km including 750 m of high-speed running as well as approximately 250 m sprint, and execute 80-155 accelerations during a game (Atan, Foskett, & Ali, 2016; Harley, et al., 2010; Pettersen & Brenn, 2019; Rebelo, Brito, Seabra, Oliveria, & Kursrup, 2014; Vigh-Larsen, Dalgas, & Andersen, 2018). So, soccer players must develop a high level of aerobic and anaerobic endurance to recover quickly from these high-intensity intermittent efforts and sustain their performance throughout the game (Bishop & Spencer, 2004). Many studies investigated the effects of running-based training for maintaining optimum aerobic and anaerobic performance throughout the game (Dupont, Akakpo, & Berthoin, 2004; Ferrari Bravo, et al., 2008; Iaia, Rampinini, & Bangsbo, 2009a; Iaia, et al., 2009b, 2015). The studies suggested that speed endurance training enabled athletes to perform high-intensity activities throughout a game more often and longer and that it reduced recovery time after high-intensity activities (Iaia, et al., 2009b, 2015). Moreover, studies showed that speed endurance training improved performance in repeated sprints (1.9-2.1%) (Ferrari Bravo, et al., 2008) and maximal aerobic speed running (8.1%) (Dupont, et al., 2004), and Yo-Yo intermittent recovery (IR) test (22-28%) (Iaia, et al., 2009a).

Most coaches have traditionally used running drills without the ball to increase soccer players' aerobic and anaerobic endurance as in many studies. However, it was proved that SSG twice a week in similar training improved aerobic endurance (Harrison, Kilding, Gill, & Kinugasa, 2014; Hill-Haas, Rowsell, Counts, & Dawson, 2008; Hill-Haas, Rowsell, Dawson, & Counts, 2009; Impellizzeri, et al., 2006; Los Arcos, et al., 2015). While one study found that SSG training enabled significantly greater progress in aerobic endurance than interval training after an 8-week intervention (Radziminski, Rompa, Barnat, Dargiewicz, & Jastrzebski, 2013), some other studies showed that the two training methods had a similar influence on aerobic endurance in young soccer players (Impellizzeri, et al., 2006; Los Arcos, et al., 2015). According to Selmi et al. (2020) and Los Acros et al. (2015), high intensity interval training (HIIT) and SSG sessions induced similar aerobic responses, while SSG induced a higher enjoyment level than HIIT. Furthermore, HIIT and SSG showed no significant difference in heart rate, rating of perceived exertion and blood lactate responses of youth soccer players (Selmi, et al., 2020). Moreover, SSG as a game-based training improves aerobic and anaerobic performance just as much as running-based training. Furthermore, during SSG, players improve their technical and tactical aspects (Radziminski, et al., 2013) and experience similar situations to those they encounter in competitive matches (Hill-Haas, et al., 2009; Sarmento, et al., 2018).

Although many comparative studies have reported progress in performance parameters for game-based training (Hill-Haas, et al., 2009**,** 2008; Sarmento, et al., 2018) and MAS training (Clemente, et al., 2020a) in youth soccer, to our knowledge, few studies have reported effects of combined training with SSG on performance parameters in young players (Akdogan, Yilmaz, Köklü, Alemdaroğlu, & Cerrah, 2021; Arslan, et al., 2021). A recent systematic review (Clemente & Sarmento, 2021) showed that combining SSGs and running-based training methods was effective. It showed that, compared to an intervention using solely SSGs, employing SSGs in combination with running-based training methods resulted in higher external and internal load values and greater increases in overall fitness capacity. Therefore, more research is needed to understand the efficiency of combined training for young players.

The aim of this research was to compare parameters of sprint, agility, blood lactate accumulation, repeated sprint, aerobic, and anaerobic endurance performances of young male soccer players between the MAS, SSG, and CT methods. In this context, two hypotheses were set: (1) MAS combined with SSG training would cause significantly greater changes in sprint, agility, lactate accumulation, repeated sprint, aerobic, and anaerobic endurance performances than the MAS training. (2) MAS combined with SSG training would cause significantly greater changes in sprint, agility, lactate accumulation, repeated sprint, aerobic, and anaerobic endurance performances than the SSG training. If the MAS combined with SSGs would enhance players' performance to a greater extent within a similar training period than MAS and SSG separately, coaches will have proof of a more efficient training.

Methods

Participants

Thirty male soccer players ($Mean_{Age}$=15.40±0.90 years; $Mean_{Height}$=173.00±5.26 cm; $Mean_{Weight}$=59.61±6.86 kg) voluntarily participated in the research. All players were members of the Eskişehir DSI Bentspor competing in the elite academy leagues. They trained at least five days per week during their training cycle in their seasons. The study was carried out in accordance with the Helsinki Declaration, and a university research ethics committee granted approval for it (No: 80558721/186). All players and parents were briefed on the research procedures, requirements, benefits, and risks prior to giving informed consent.

Research design

The research of pre-post-test design was completed in 12 weeks and considered three training intervention groups using MAS, SSG, and CT for six weeks (Figure 1).

Prior to the experimental training period, all subjects performed a comprehensive 4-week aerobic training program consisting of 60-90 minutes of low-intensity activity (low-intensity running, dynamic stretching, and short passing) five days per week to adapt to training and prevent any injuries.

After the adaptation period, all players were subjected to 5-day testing. On the first day, body weight and body height were measured, and sprint tests (10 m, 20 m, and 30 m) were performed, whereas the Yo-Yo 1 intermittent recovery test was performed on the second day. Arrowhead agility and blood lactate tests were performed on the third day. After one day of rest, the Yo-Yo 2 intermittent recovery test was performed on the fifth day.

The soccer-specific field and laboratory tests above were used together to better understand the physiological demands and dynamic nature of soccer (Svensson & Drust, 2005). The participants were tested on natural grass wearing soccer shoes in field tests. All the players were briefed about avoiding caffeine consumption, refraining from strenuous physical activity for eight hours, and eating a light meal three hours before the test days. Before the tests, the participants completed a 15-minute warm-up session, consisting of 8-minute low-intensity jogging, four minutes of 40-60 m accelerations and decelerations, and three minutes of dynamic stretching for the hamstrings, hip extensors and flexors, and quad group muscles. All the trials were performed at the same hours (9:30-11:30 a.m.) of the day to minimize the effects of circadian variation (Reilly & Brooks, 1986). The temperature was between 18° and 25°C and humidity was between 40% and 47.1%.

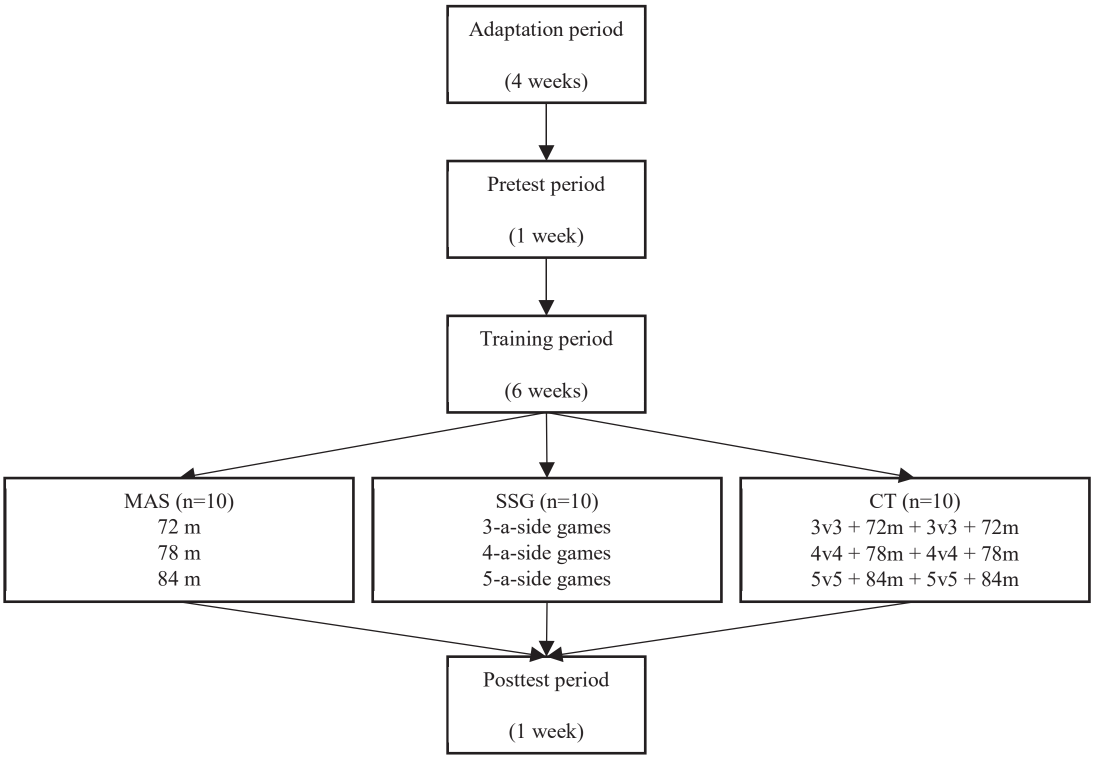

Figure 1. The research design

Randomization and pre-test comparisons were used for the control of unbiased assignment of participants to groups. After the pre-tests were done, the players were randomly grouped based on the Yo-Yo 1 test as MAS, SSG, or CT. No differences were found between the participants in the Yo-Yo 1 pre-tests. The groups trained by the intervention program two days per week (on Tuesdays and Thursdays) during the 6-week experimental period. All training programs started with a 25-minute warm-up (low-intensity running, dynamic stretching, and short passing) and finished with a 10-minute cooldown (jogging, stretching). No other training was performed on the intervention days.

On other days of the 6-week experimental period, training sessions started with warm-up exercises (low-intensity running, dynamic stretching, and short passing) and continued with technical and tactical exercises in small and large groups and finished with a game-based training (commonly 8-a-side or 9-a-side game). After the intervention training period, the research was completed with the post-test period.

Body composition and body height

Dual Energy X-Ray Absorptiometry (DEXA) (Lunar Prodigy Pro; GE, Healthcare, Madison, WI, USA) was used to test the participants' body composition (total mass, fat mass, lean mass, fat-free mass, total region % fat). A height meter (SECA-707) with 0.01 cm sensitivity was used to measure participants' body height.

Blood lactate accumulation

The Lactate Scout set (Barleben, Magdeburg, Germany) was used to take 0.2 µl of capillary blood samples from the fingers of the participants for the determination of blood lactate accumulation using the enzymatic amperometric detection method.

Arrowhead agility test

Arrowhead agility test, developed specifically for soccer, was performed three times with a 5-min recovery between the trials (Rago, et al., 2020). The starting point was 30 cm behind the first light sensor (Gunnarsson, Christensen, Holse, Christiansen, & Bangsbo, 2012).

Sprint 10-20-30 m tests

Sprint performance was tested on natural grass fields (the participants wore soccer boots). Three attempts were performed with 3-min breaks between them and the best sprint time was recorded. All data were recorded using a computer-connected Smartspeed (Fusion Sport Pty Queensland, Australia), with light sensors placed at 0, 10, 20, and 30 m distances. The starting point was 30 cm behind the first light sensor (Gunnarsson, et al., 2012).

Repeated-sprint test

Repeated-sprint performance test, developed by Bangsbo (1994), consists of seven asymmetric runs on a 34.2-meter running track and an active recovery period of 25 seconds between the repetitions (Wragg, Maxwell, & Doust, 2000). The participants were tested wearing soccer shoes on natural grass with a 25-second rest between the sprints. They started the test by standing on a marked line 30 cm behind the first light sensor (Gunnarsson, et al., 2012). All data were recorded using a computer-connected Smartspeed (Fusion Sport Pty Queensland, Australia), with photoelectric cells placed at the start and finish line. The fatigue index, the ideal time, total sprint time, and performance decrement were used for the repeated sprint analysis. While the ideal time is the best time of seven runs, the total sprint time is the sum of seven runs. The fatigue index is determined by the difference between the 1st and 2nd run and the 6th and 7th run. The decrease in sprint performance was calculated by the following method (Spencer, Fitzsimos, Dawson, Bishop, & Goodman, 2006):

Performance decrement (%) = 100 - (Total time / Ideal time x 100)

Yo-Yo intermittent recovery tests

Yo-Yo 1 and Yo-Yo 2 tests were developed for soccer. Both tests consist of 2 x 20 m shuttle runs. The running speed, which progressively increases, is controlled by audio bleeps. While the Yo-Yo 1 started at the speed of 10 $km.h^{-1}$, Yo-Yo 2 started at 13 $km.h^{-1}$. If the participants cannot reach the lines twice in the allotted time, they are considered to have finished their tests. The participants were tested wearing soccer shoes on natural grass with a 10-s rest between each running bout (Bangsbo, Iaia, & Krustrup, 2008; Krustrup, et al., 2003).

Training programs

All the groups performed 12 intervention training sessions each lasting 40 minutes. All training methods were performed in four sets with a 3-minute rest on a natural grass field where the players played their matches. Each workout set lasted four minutes. in all training methods. Details of the training methods are given in Table 1. The participants were encouraged to exert maximum effort during the training as suggested (Radziminski, et al., 2013).

Maximal aerobic speed (MAS) training

The training had 12 sessions of 72 m, 78 m, and 84 m sprints with 110%, 120%, and 130% intensity, respectively. Each session consists of eight repetitions, which is 15 seconds sprint and 15 seconds rest. A gradual progress plan was designed to reach the final performance in MAS training. The participants progressively ran all-out for 72 m in the first two weeks, 78 m in the 3rd and 4th week, and 84 m in the 5th and 6th week (Table 1).

Small-sided games (SSG) training

The SSGs were performed on a natural grass field for 4 x 4 min with 3-min rests. During the first two weeks, 3-a-side SSGs were played in an 18 m x 30 m playing area. During the 3rd and 4th week, 4-a-side SSGs were played in a 24 m x 36 m playing area. During the 5th and 6th week, 5-a-side games were played in a 36 m x 42 m (Table 1). There were extra balls next to the lines of the pitches and in the goals to enable the game to be re-started if the ball left the playing area.

Combined training (CT)

Combined training consisted of both the SSGs and MAS programs. After the SSG ended, the participants performed MAS over 100 m on a pitch in which they had to turn 180° when reached the sideline. During weeks one and two, the participants played two times one 3-a-side SSG in an 18 m x 30 m playing area followed by a 72 m sprint. During the 3rd and 4th weeks, the participants played 4-a-side SSG in a 24 m x 36 m area and then ran 78 m sprints, repeated twice. During the 5th and 6th weeks, a 5-a-side SSG was played in a 36 m x 42 m area followed by 84 m sprints, repeated twice. All sprints were repeated eight times, which is 15 seconds sprint and 15 seconds rest in the MAS part of CT. The intensity of training progressively increased (110%, 120%, and 130%), respectively, in the MAS part of CT (Table 1).

Global positioning system (GPS)

Training sessions were monitored with a GPS that sampled at 10 Hz and provided speed and distance data. GPSports EVO GPS, which is a valid and reliable technology for measuring distance and displacement (Johnston, et al., 2012), was used for tracking the changes in external and internal load with an integrated heart rate tool between the training methods. Total distance, speed zones, training load, max heart rate, average heart rate, average velocity, and max velocity were recorded in the tracking (Table 2). All data were recorded using a computer-connected GPSports EVO GPS. It is suggested that measuring the rating of perceived exertion (RPE) in small-sided games is useful in tracking training intensity (Coutts, Rampinini, Marcora, Castagna, & Impellizzeri, 2009). Therefore, GPS and RPE were used together. During the pre-test period, players gained experience and became familiar with GPS technology and RPE.

Table 1. Training programs

	MAS				SSG	CT			
Week-session	Training / Rest (s)	Repetition	Intensity (%)	Distance (m)	Side Games - Area (m)	Side Games + Distance (m)	Number of sets/ Rests (min)	Set time (min)	Total volume (min)
1-1	15s/15s	8	%110	72	3v3 - 18x30	3v3 + 72m + 3v3 + 72m	4/3	4	480
1-2	15s/15s	8	%110	72	3v3 - 18x30	3v3 + 72m + 3v3 + 72m	4/3	4	
2-1	15s/15s	8	%110	72	3v3 - 18x30	3v3 + 72m + 3v3 + 72m	4/3	4	
2-2	15s/15s	8	%110	72	3v3 - 18x30	3v3 + 72m + 3v3 + 72m	4/3	4	
3-1	15s/15s	8	%120	78	4v4 - 24x36	4v4 + 78m + 4v4 + 78m	4/3	4	
3-2	15s/15s	8	%120	78	4v4 - 24x36	4v4 + 78m + 4v4 + 78m	4/3	4	
4-1	15s/15s	8	%120	78	4v4 - 24x36	4v4 + 78m + 4v4 + 78m	4/3	4	
4-2	15s/15s	8	%120	78	4v4 - 24x36	4v4 + 78m + 4v4 + 78m	4/3	4	
5-1	15s/15s	8	%130	84	5v5 - 36x42	5v5 + 84m + 5v5 + 84m	4/3	4	
5-2	15s/15s	8	%130	84	5v5 - 36x42	5v5 + 84m + 5v5 + 84m	4/3	4	
6-1	15s/15s	8	%130	84	5v5 - 36x42	5v5 + 84m + 5v5 + 84m	4/3	4	
6-2	15s/15s	8	%130	84	5v5 - 36x42	5v5 + 84m + 5v5 + 84m	4/3	4	

Statistical analysis

In the research, whether there was a statistically significant difference between the pre-test and post-test performance of the three groups was determined by using two-factor ANOVA. The assumptions of normality, homogeneity of variance, and equality of covariance for the ANOVA were checked before running the analysis (Can, 2016). In addition, whenever the interaction effect was significant, further *post-hoc* analyses (Scheffe) were conducted through one-way ANOVA as a follow up test for analysis of simple effects (Pallant, 2011). Cohen's (1988) partial eta squared (η^2) effect sizes (ESs) and thresholds (.00, .06, and .14 as benchmarks for small, medium, and large effect sizes, respectively) were used to compare the magnitude of the differences in performance parameters between the training groups. SPSS 25 package program was used in the analysis of the data.

Results

The CT group had higher changes in total mass ($F_{2,27}$=4.307, p=.024, η^2=.242), fat mass ($F_{2,27}$=3.732, p=.037, η^2=.217), lean mass ($F_{2,27}$=4.169, p=.026, η^2=.236), and total region % fat ($F_{2,27}$=3.986, p=.030, η^2=.228), 7x34.2 TST ($F_{2,27}$=9.394, p=.001, η^2=.212), Yo-Yo 1 ($F_{2,27}$=11.535, p=.000, η^2=.457), and Yo-Yo 2 ($F_{2,27}$=4.116, p=.028, η^2=.234) compared to the MAS training group. There were no significant changes in fat-free mass, sprint tests (10 m, 20 m, and 30 m), 7x34.2 performance decrement, resting lactate, post-test lactate, lactate 3-minutes after the test, or fatigue index between the training groups ($p>.05$) (Table 3).

Discussion and conclusions

The purpose of this research was to compare the effects of maximal aerobic speed (MAS) training, small-sided games (SSG) training, and combined training (CT) on sprint, agility, repeated sprint, aerobic, and anaerobic endurance performances in young male soccer players.

Two hypotheses were written for this purpose: (1) MAS combined with SSG training would cause significantly greater changes in sprint, agility, lactate accumulation, repeated sprint, aerobic, and anaerobic endurance performances than the MAS training. (2) MAS combined with SSG training would cause significantly greater changes in sprint, agility, lactate accumulation, repeated sprint, aerobic, and anaerobic endurance performances than the SSG training. While the hypothesis between MAS and CT on all performance parameters was not rejected, the hypothesis between

Table 2. GPS data of the training groups

GPS data	Training groups	Training period		
		Weeks 1 and 2	Weeks 3 and 4	Weeks 5 and 6
Total distance (m)	MAS	2417.98	2499.93	2678.63
	SSG	2036.89	1757.04	1751.61
	CT	2144.62	2226.93	2152.49
Z1-Z3 (<18km) (m)	MAS	1665.40	929.80	1046.98
	SSG	1989.75	1732.73	1735.30
	CT	1587.85	1313.25	1362.17
Z4 (18-21 km) (m)	MAS	704.56	1180.6	934.83
	SSG	41.62	21.40	14.69
	CT	514.35	484.18	338.66
Z5 (21-24 km) (m)	MAS	48.02	366.73	652.91
	SSG	5.52	2.91	1.62
	CT	42.42	406	430.66
Z6 (>24 km) (m)	MAS	0	22.80	43.91
	SSG	0	0	0
	CT	0	23.50	21
Training load	MAS	40.95	45.10	47.65
	SSG	33.125	31.90	28.80
	CT	27.60	29.35	20.90
Max HR (min/HR)	MAS	194.25	172.70	193.40
	SSG	189.425	183.85	183.40
	CT	194.90	196.25	196.05
Average HR (min/HR)	MAS	166.60	148.30	164.90
	SSG	165.03	165.05	159.45
	CT	167.68	164.65	167.65
Average velocity (m/s)	MAS	8.05	9.30	10
	SSG	6.73	7	6.85
	CT	8	8.25	7.80
Maxi velocity (m/s)	MAS	22.43	25.05	25.35
	SSG	21	20.30	19.95
	CT	22.38	24.30	25
Average velocity (m/min)	MAS	112.33	116.85	114.45
	SSG	132.98	137.50	130.75
	CT	134.475	155.05	167
RPE	MAS	6.90	7.20	8
	SSG	6	6.40	6.40
	CT	5.80	6.60	7.70

Note. Z=zone, Max=maximum, HR=heart rate, RPE=rating of perceived exertion.

SSG and CT on some performance parameters was rejected. In other words, there are two main findings of this research. One of them was that the CT group showed higher progress in body composition, repeated sprint, aerobic and anaerobic endurance parameters compared to the MAS training group. The other one of them was that the SSG group had similar changes to the CT group in all performance parameters.

These results are in concordance with previous studies in terms of the aerobic, anaerobic, sprint, repeated sprint, and post-lactate tolerance responses. Akdogan et al. (2021) reported that SSG produced similar Yo-Yo 1 and repeated sprint responses as CT (SSG and SER-speed endurance training) in young soccer players. Another study (Selmi, et al., 2020) showed no significant differences between HIIT and SSG in post-blood lactate of young soccer players. Previously, it was reported that SSG and interval training had a similar effect on aerobic fitness of young soccer players (Los Acros, et al., 2015). Another study (Radziminski, et al., 2013)

Table 3. Means and standard deviations for body composition, sprint, agility, repeated sprint, aerobic, and anaerobic endurance (Mean±SD)

Variables	Groups	Pretests	Posttests	F	p	η²	Post-hoc Scheffe
Total mass (kg)	MAS (n=10)	59.81±8.32	60.46±7.79	G=.467	.632	.033	CT>MAS
	SSG (n=10)	60.73±7.68	61.30±7.88	T=2.941	.098	.098	
	CT (n=10)	58.29±4.47	57.89±4.37	GxT=4.307	.024	.242	
Fat mass (kg)	MAS (n=10)	9.88±2.57	9.01±2.37	G=.082	.922	.006	CT>MAS
	SSG (n=10)	9.86±2.57	8.86±2.17	T=155.058	.000	.852	
	CT (n=10)	9.80±1.51	8.37±.72	GxT=3.732	.037	.217	
Lean mass (kg)	MAS (n=10)	47.03±7.03	49.12±7.09	G=.446	.645	.032	CT>MAS
	SSG (n=10)	48.09±5.53	49.85±5.64	T=129.916	.000	.828	
	CT (n=10)	46.06±3.95	47.15±3.88	GxT=4.169	.026	.236	
Fat free mass (kg)	MAS (n=10)	50.05±7.31	51.65±7.31	G=.488	.619	.035	
	SSG (n=10)	50.81±5.63	52.36±5.99	T=100.375	.000	.788	
	CT (n=10)	48.48±4.10	49.64±4.09	GxT=.948	.400	.066	
Total region % fat (%)	MAS (n=10)	16.44±4.06	14.92±3.70	G=.104	.902	.008	CT>MAS
	SSG (n=10)	16.08±2.49	14.29±2.03	T=219.637	.000	.891	
	CT (n=10)	16.84±1.72	14.45±1.32	GxT=3.986	.030	.228	
10 m sprint(s)	MAS (n=10)	1.74±.04	1.68±.04	G=2.661	.088	.165	
	SSG (n=10)	1.73±.04	1.66±.06	T=50.247	.000	.650	
	CT (n=10)	1.78±.04	1.70±.08	GxT=.200	.820	.015	
20 m sprint (s)	MAS (n=10)	3.04±.07	2.99±.10	G=4.007	.030	.229	
	SSG (n=10)	3.00±.07	2.92±.10	T=22.580	.000	.455	
	CT (n=10)	3.12±.10	3.03±.14	GxT=.738	.487	.052	
30 m sprint (s)	MAS (n=10)	4.30±.10	4.25±.17	G=4.744	.017	.260	
	SSG (n=10)	4.23±.10	4.13±.16	T=15.976	.000	.372	
	CT (n=10)	4.43±.14	4.29±.20	GxT=1.237	.306	.084	
Arrowhead agility (s) (best right)	MAS (n=10)	8.41±.13	8.25±.17	G=1.546	.231	.103	
	SSG (n=10)	8.44±.21	8.30±.25	T=193.675	.000	.878	
	CT (n=10)	8.61±.31	8.41±.30	GxT=2.344	.115	.148	
Arrowhead agility (s) (best left)	MAS (n=10)	8.51±.16	8.33±.19	G=.802	.459	.056	
	SSG (n=10)	8.58±.33	8.44±.29	T=118.781	.000	.815	
	CT (n=10)	8.67±.29	8.47±.30	GxT=1.430	.257	.096	
7x34.2 TST (m)	MAS (n=10)	37.86±1.26	36.56±.85	G=3.632	.040	.212	CT>MAS
	SSG (n=10)	36.59±.79	36.03±.62	T=181.607	.000	.871	
	CT (n=10)	38.12±1.33	36.84±1.19	GxT=9.394	.001	.410	
7x34.2 PD (%)	MAS (n=10)	7.79±1.53	6.29±1.13	G=5.002	.014	.270	
	SSG (n=10)	6.47±2.25	5.62±1.71	T=11.085	.003	.291	
	CT (n=10)	5.06±1.74	4.89±1.02	GxT=2.315	.118	.146	
Resting LA (mmol/L)	MAS (n=10)	1.53±.17	1.43±.18	G=1.293	.291	.087	
	SSG (n=10)	1.49±.13	1.20±.34	T=15.265	.001	.361	
	CT (n=10)	1.57±.11	1.26±.39	GxT=1.424	.258	.095	
Posttest LA (mmol/L)	MAS (n=10)	7.89±1.85	6.73±.99	G=1.338	.279	.090	
	SSG (n=10)	8.70±2.37	8.13±2.17	T=7.644	.010	.221	
	CT (n=10)	8.00±1.91	6.95±1.63	GxT=.292	.749	.021	
LA 3min (mmol/L)	MAS (n=10)	12.85±1.45	11.87±1.83	G=1.198	.317	.081	
	SSG (n=10)	12.75±2.80	12.41±1.96	T=3.042	.092	.101	
	CT (n=10)	11.79±1.77	11.21±1.42	GxT=.264	.770	.019	
Fatigue index	MAS (n=10)	7.79±1.53	6.29±1.13	G=5.002	.014	.270	
	SSG (n=10)	6.47±2.25	5.62±1.71	T=11.085	.003	.291	
	CT (n=10)	5.06±1.74	4.89±1.03	GxT=2.315	.118	.146	
Yo-Yo 1 (m)	MAS (n=10)	1080±215.82	1828±275.23	G=11.527	.000	.461	CT>MAS
	SSG (n=10)	1264±213.50	2120±458.40	T=350.401	.000	.928	
	CT (n=10)	1356±273.54	2676±288.72	GxT=11.355	.000	.457	
Yo-Yo 2 (m)	MAS (n=10)	384±162.43	516±160.50	G=2.222	.128	.141	CT>MAS
	SSG (n=10)	464±126.77	620±125.43	T=203.509	.000	.883	
	CT (n=10)	488±184.56	700±178.14	GxT=4.116	.028	.234	

Note. MAS=maximal aerobic speed training group, SSG=small-sided games training group, CT=combined training group; TST=total sprint time, PD=performance decrement, LA=lactate accumulation.

found that an 8-week SSG and high-intensity interval running training had a similar effect on the aerobic and anaerobic capacity, sprint, and repeated sprint of young soccer players. The results of these studies suggest SSGs were at least equally effective in developing aerobic and anaerobic capacity, sprint, and repeated sprint abilities as much as running-based training. Considering that SSG is a drill-based exercise that also improves tactical/technical dimensions in soccer training (Clemente, et al., 2020) and offers more fun to young players than running-based training (Los Acros, et al., 2015; Selmi, et al., 2020), it can be suggested that coaches should prefer SSGs for the sustainability of young players' training.

Findings revealed that CT was more effective than MAS training in improving repeated sprint, aerobic and anaerobic endurance parameters and had similar effects as SSG training on all performance parameters after a 6-week intervention training. The research compared the effects of MAS, SSG, and CT methods in youth male soccer by tracking the changes in external and internal load with a GPS. In this respect, it removes the limitations of previous studies (Akdogan, et al., 2021; Dellal, et al, 2008) and offers more reliable results to coaches and sports scientists. Therefore, coaches and sports scientists who adopt game-based training are advised to choose CT consisting of running drills with and without the ball for more efficient training. Furthermore, findings of the 6-week randomized training study revealed that MAS, SSG, and CT methods had similar effects on sprint, agility, and blood lactate accumulation.

This research poses some limitations; therefore, the findings should be interpreted with caution. First, research was designed as a short-term randomized training. Second, due to the research design, the positions of the players were also randomly distributed among the groups. This research should be replicated with specific players' positions from different age categories to generalize findings and to different challenge environments. Moreover, further studies should think of designing a long-term randomized training that can help investigators to see the influences of MAS, SSG, and CT on sprint and blood lactate accumulation parameters.

In conclusion, the results of the six-week randomized training study indicated that CT and SSG training provoked similar changes in body composition, sprint, agility, blood lactate accumulation, repeated sprint, and aerobic and anaerobic endurance performance, whereas the CT and MAS training had similar changes only in sprint, agility, and blood lactate accumulation performance parameters. In other words, in young male soccer players, CT was more effective in developing body composition, repeated sprint, and aerobic and anaerobic endurance performances compared to MAS training and the SSG training was at least equally effective in developing all parameters compared to CT training.

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