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SYSTEMATIC REVIEW

Effects of Small-Sided Games vs. Conventional Endurance Training on Endurance Performance in Male Youth Soccer Players: A Meta-Analytical Comparison

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Abstract

Background Small-sided games have been suggested as a viable alternative to conventional endurance training to enhance endurance performance in youth soccer players. This has important implications for long-term athlete development because it suggests that players can increase aerobic endurance through activities that closely resemble their sport of choice.

Objectives The objectives of this meta-analysis were to compare male youth soccer players' adaptability to small-sided games vs. conventional endurance training and to establish exercise prescription guidelines for this population.

Data Sources The data sources utilised were Google Scholar, PubMed and Microsoft Academic.

Study Eligibility Criteria Studies were eligible for inclusion if interventions were carried out in male soccer players (aged < 18 years) and compared the effects of small-sided games and conventional endurance training on aerobic endurance performance. We defined small-sided games as "modified [soccer] games played on reduced pitch areas, often using adapted rules and involving a smaller number of players than traditional games". We defined conventional endurance training as continuous running or extensive interval training consisting of work durations > 3 min.

Study Appraisal and Synthesis Methods The inverse-variance random-effects model for meta-analyses was used because it allocates a proportionate weight to trials based on the size of their individual standard errors and facilitates analysis whilst accounting for heterogeneity across studies. Effect sizes were represented by the standardised mean difference and presented alongside 95% confidence intervals.

Results Seven studies were included in this meta-analysis. Both modes of training were effective in increasing endurance performance. Within-mode effect sizes were both of moderate magnitude [small-sided games: 0.82 (95% confidence interval 0.05, 1.60), $Z=2.07$ ($p=0.04$); conventional endurance training: 0.89 (95% confidence interval 0.06, 1.72), $Z=2.10$ ($p=0.04$)]. There were only trivial differences [0.04 (95% confidence interval − 0.36, 0.43), $Z=0.18$ ($p=0.86$)] between the effects on aerobic endurance performance of small-sided games and conventional endurance training. Subgroup analyses showed mostly trivial differences between the training methods across key programming variables such as set duration (≥ or < 4 min) and recovery period between sets (≥ or < 3 min). Programmes that were longer than 8 weeks favoured small-sided games [effect size = 0.45 (95% confidence interval − 0.12, 1.02), $Z=1.54$ ($p=0.12$)], with the opposite being true for conventional endurance training [effect size = − 0.33 (95% confidence interval − 0.79, 0.14), $Z=1.39$ ($p=0.16$)]. Programmes with more than 4 sets per session favoured small-sided games [effect size = 0.53 (95% confidence interval − 0.52, 1.58), $Z=0.98$ ($p=0.33$)] with only a trivial difference between those with 4, or fewer, sets [effect size = − 0.13 (95% confidence interval − 0.52, 0.26), $Z=0.65$ ($p=0.52$)].

Conclusions Small-sided games are as effective as conventional endurance training for increasing aerobic endurance performance in male youth soccer players. This is important for practitioners as it means that small-sided games can allow both endurance and skills training to be carried out simultaneously, thus providing a more efficient training stimulus. Small-sided games offer the same benefits as conventional endurance training with two sessions per week, with ≥ 4 sets of 4 min of activity, interspersed with recovery periods of 3 min, recommended in this population.

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Key Points

Small-sided games are an effective method for the development of endurance in male youth soccer players and can be used to achieve the same performance improvements as conventional endurance training.

The use of small-sided games in soccer could maximise skill development at an early age and help to maintain motivation in younger players, whilst also addressing the physiological demands of the sport.

Small-sided games programmes should comprise two sessions per week, with 4 or more sets of 4 min of activity, interspersed with recovery periods of 3 min.

1 Introduction

Soccer is a high-intensity sport of intermittent bouts of activity, which places a substantial demand on the aerobic system [1]. Aerobic energy contributes approximately 90% of the total energy cost during competitive play [1] and aerobic fitness profiles are strongly related to performance-orientated outcomes [2, 3]. Conventional endurance training (CET), such as steady-state or extensive interval training, has traditionally been part of soccer coaches' aerobic training programmes as it can enhance endurance capabilities [4]. However, despite the effectiveness of this type of training on maximal oxygen uptake ($\dot{V}O_{2max}$) enhancement, running economy and blood lactate profiles [4], CET does not necessarily mimic the intermittent activity profile of a soccer match and does not require the player to perform relevant soccer skills whilst under fatigue [5]. This is an important element that needs to be addressed by soccer coaches because fatigue has been shown to negatively impact upon skill performance [6], thus necessitating training methods that can improve a player's performance during periods of relatively higher intensity. To this end, small-sided games [SSGs (i.e. soccer played on a smaller sized pitch with fewer than the usual 11 players per team)] have been used by coaches to simultaneously target both endurance capacity and technical skill development [5]. This constitutes an efficient training solution that directly addresses the primary demands of soccer play.

Recently, Hammami et al. [7] summarised the effects of SSGs across 16 studies drawn from multiple sports and population types. The authors concluded that SSGs were more effective for the development of skill and endurance than traditional conditioning or training. However, owing to the diverse nature of the studies included in the meta-analysis (i.e. multiple sports in adults and children of both sexes), the authors could not make more focused recommendations based on sport and population type. Because different team sports such as soccer, rugby and field hockey place a diverse spectrum of demands on players, it is important for coaches to be able to determine the effectiveness of SSGs in the specific sport within which they operate. Moreover, population-specific recommendations are also important given the differences in adaptations to exercise between adults and youths [5], as well as male and female individuals [8].

There is a large amount of research [9–14] on SSGs in soccer that assesses acute responses to exercise in young players and effective game format configurations. This information is often then used as a basis for long-term SSG programme prescription despite the short-term, and cross-sectional, nature of the originally gathered data. Several studies have been conducted and these studies examine a wide variety of different training variables for SSGs such as player numbers [9], pitch size [10], game rules [11] and player behaviour [12] amongst other considerations [13, 14]. Though these recommendations are founded upon research that is mostly sound, as yet there has been no quantitative summary on the effects of longer term SSG interventions, as compared to CET, in youth soccer players. Similarly, there is no statistically supported consensus on how training variables, such as the number of sets, work set duration and recovery period, influence adaptations to SSG. These are important factors for coaches to consider when aiming to improve aerobic performance in youth players who may be highly susceptible to overtraining and burnout, which could lead to injury or abstinence from soccer, especially considering the congested tournament configuration in some competitions [15].

Given that SSGs can serve as a time- and skill-efficient solution to meeting the demands of soccer, an investigation into their effects compared to CET in youth soccer players is warranted. Therefore, the main purpose of this systematic review and meta-analysis was to compare the effects of SSGs and CET on aerobic endurance performance in male youth soccer players. A secondary aim was to establish clear guidelines for the prescription of SSG training in youth soccer players.

2 Methods

This meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [16]. The literature search was performed by JM and the data extraction and verification were carried out by JM and JF.

2.1 Literature Search

With no date restrictions, a systematic search of the Google Scholar, PubMed and Microsoft Academic was undertaken. Only articles published in the English language were considered. These searches were performed in May 2018. Using Boolean logic, we used the search terms: 'youth' AND 'training' AND 'small sided games' AND 'soccer' OR 'football' OR 'skill' OR 'endurance'. In selecting studies for inclusion, a review of all relevant article titles was conducted before an examination of article abstracts and, then, full published articles. Only peer-reviewed articles were included in the meta-analysis. Following the formal systematic searches, additional hand searches were conducted. The search process is outlined in Fig. 1.

2.2 Inclusion and Exclusion Criteria

Data were extracted from gathered articles with a form created in Microsoft Excel. The following criteria determined the eligibility of studies for inclusion in the review: studies that applied a SSG programme of 4 weeks or more; cohorts of healthy male soccer players, with a mean age between 8 and 18 years; group mean baseline and follow-up data outcome measures relating to endurance performance; and a comparison group that was engaged in CET. As it can be

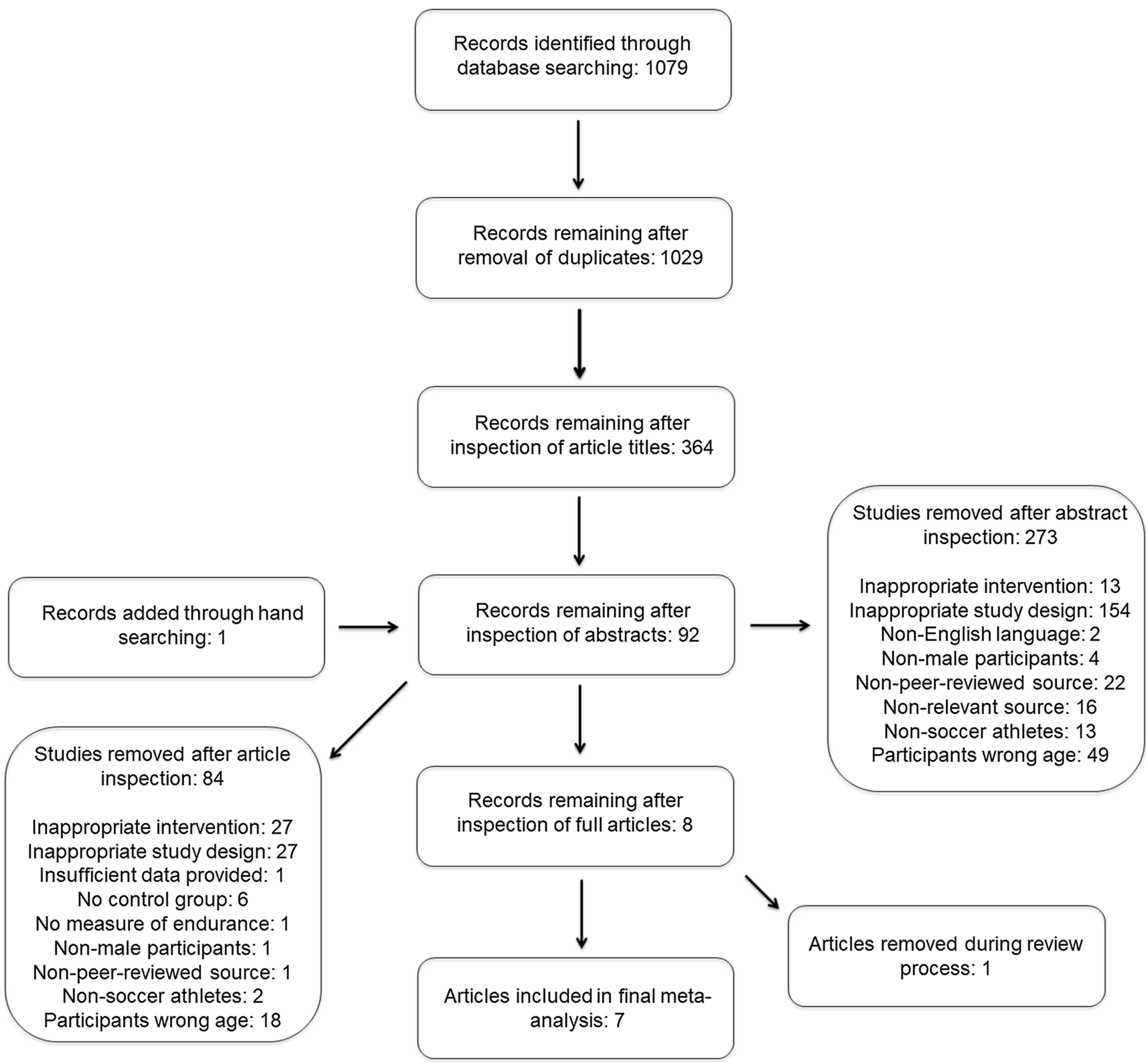


Fig. 1 Flow chart for inclusion and exclusion of studies

inherently difficult to ensure a training study meets all of the criteria that determine if it can be considered of high quality [38], we did not stipulate that researchers must have randomised their participants. This also helped to maximise includable data. We defined SSG as "modified [soccer] games played on reduced pitch areas, often using adapted rules and involving a smaller number of players than traditional games" [17]. We defined CET as continuous running or extensive interval training consisting of work durations > 3 min [18].

We chose studies with a minimum duration of 4 weeks to account for the potentially slow time course of adaptation to aerobic training in youth [19, 20], as well as the unpredictable nature of SSG training, which may require a period of habituation over a number of weeks. We included male individuals only because the pooling of performance data of both female and male individuals for analysis within the same studies is not an acceptable practice in research as it only determines whether a training method is effective independent of any population-specific effects. Such an approach would not have considered the effects of sex and maturation level on training status given that boys and girls are biologically different and experience different maturational changes at varying times [8].

The outcome variable of interest was $\dot{V}O_{2max}$, measured directly, or indirectly via a field test. This was rationalised on the basis that aerobic metabolism is the primary pathway of energy production in soccer [3] and it can be enhanced in players through the use of SSGs [20]. If $\dot{V}O_{2max}$ was unavailable, we were satisfied to include studies that assessed endurance performance by means of other measures such as multi-stage fitness tests, basing this on a logically defensible rationale. This is an accepted method of study-inclusion justification in a meta-analysis [21] and is used elsewhere in the literature on training in youth athletes [8, 22]. Observational studies that lacked a clear description of the applied training stimulus were not considered. Similarly, studies that involved any form of dietary manipulation (i.e. supplementation or fasting) were not considered. The characteristics of the study participants and training programmes are displayed in Tables 1 and 2, respectively.

2.3 Analysis and Interpretation of Results

Meta-analytical comparisons were carried out in RevMan Version 5.3 [29]. Means and standard deviations for a measure of post-intervention endurance performance were used to calculate an effect size (ES). The inverse-variance random-effects model for meta-analyses was used because it allocates a proportionate weight to trials based on the size of their individual standard errors [30] and facilitates analysis whilst accounting for heterogeneity across studies. Effect sizes are represented by the standardised mean difference and are presented alongside 95% confidence intervals (CIs). The calculated ESs were interpreted using the conventions outlined for a standardised mean difference by Hopkins et al. [31] (< 0.2 = trivial; 0.2–0.59 = small, 0.6–1.19 = moderate, 1.2–1.99 = large, 2.0–3.99 = very large, > 4.0 = extremely large).

To gauge the degree of heterogeneity amongst the included studies, the I^2 statistic was referred to. This represents the proportion of effects that are due to heterogeneity as opposed to chance [16]. Low, moderate and high levels of heterogeneity correspond to I^2 values of 25%, 50% and

Table 1 Characteristics of study participants

Study	Study group	Participants, *n*	Age, y (SD)	Height, cm (SD)	Body mass, kg (SD)
Eniseler et al. [23]	Small-sided games	10	17.07 (1.22)	174.0 (3.26)	65.8 (5.9)
	Repeated-sprint training	9	16.84 (1.18)	172.0 (4.82)	65.4 (5.2)
Hill-Haas et al. [24]	Small-sided games	10	14.6 (0.9)	172.0 (5.8)	62.1 (6.2)
	Generic training	9	14.6 (0.9)	172.0 (5.8)	62.1 (6.2)
Impellizzeri et al. [20]	Specific training	14	17.2 (0.8)	178.1 (5.8)	69.1 (4.7)
	Generic training	15	17.2 (0.8)	178.1 (5.8)	69.1 (4.7)
Jastrzebski et al. [25]	Small-sided games	11	15.8 (0.63)	175.0 (6.23)	61.6 (8.97)
	Interval running	11	15.8 (0.55)	177.6 (6.48)	62.7 (8.69)
Los Arcos et al. [26]	Small-sided games	7	15.1 (0.7)	176.0 (6.0)	67.0 (5.0)
	Interval training	8	15.8 (0.5)	177.0 (5.0)	69.0 (6.0)
Radziminski et al. [27]	Small-sided games	9	15.0 (0.46)	172.1 (6.55)	55.3 (7.92)
	Running	11	15.1 (0.67)	171.9 (5.35)	57.2 (9.11)
Safania et al. [28]	Small-sided games	10	15.7 (0.7)	165.34 (4.75)	58.5 (5.22)
	Interval training	10	15.7 (0.7)	165.34 (4.75)	58.5 (5.22)

SD standard deviation

Table 2 Characteristics of training programmes

Study	Study group	Weeks	Mean frequency (per week)	Total sessions	Small-sided games type	No. of sets	Set duration, min	Rest period, min	No. of players per team	Pitch length, m	Pitch width, m	Total dimensions, m^2	Goalkeepers	Exercise intensity	Test
Eniseler et al. [23]	Small-sided games	6	2	12	3 vs. 3	4	3	4	3	18	30		No	90–95% HR max	Yo-Yo Intermittent Recovery Test Level 1 (m)
	Repeated-sprint training	6	2	12										90–95% HR max	Yo-Yo Intermittent Recovery Test Level 1 (m)
Hill-Haas et al. [24]	Small-sided games	7	2	14	2 vs. 2 up to 7 vs. 7 under various conditions	3–6[a]	7–13	1–3	2–7	20–60	15–40		No	< 80% HR max to > 90% HR max	Yo-Yo Intermittent Recovery Test Level 1 [VO_{2max} ($mL\ kg^{-1}\ min^{-1}$)]
	Generic training	7	2	14										< 80% HR max to > 90% HR max	Yo-Yo Intermittent Recovery Test Level 1 [VO_{2max} ($mL\ kg^{-1}\ min^{-1}$)]
Impellizzeri et al. [20]	Specific training	12	2	24	3 vs. 3, 4 vs. 4, 5 vs. 5	4	4	3	3–5	25–40	35–50		Yes and no	90–95% HR max	Incremental treadmill ($mL\ kg^{-1}\ min^{-1}$)
	Generic training	12	2	24		4	4	3						90–95% HR max	Incremental treadmill ($mL\ kg^{-1}\ min^{-1}$)
Jastrzebski et al. [25]	Small-sided games	8	2	16	3 vs. 3	7	3	1.5	3	30	18	540	No	~ 89.5–90.5% HR max	Graded cycle test [VO_{2max} ($mL\ kg^{-1}\ min^{-1}$)]
	Interval-running	8	2	16		7	3	1.5						~ 88.5–89.5% HR max	Graded cycle test [VO_{2max} ($mL\ kg^{-1}\ min^{-1}$)]
Los Arcos et al. [26]	Small-sided games	6	1.83[b]	11	3 vs. 3 and 4 vs. 4 under various conditions	3	4	3	3–4			85	Yes and no	< 80–> 90% HR max	Continuous maximal multistage running field test ($km\ h^{-1}$)
	Interval training	6	1.83[b]	11		3	4	3						90–95% HR max	Continuous maximal multistage running field test ($km\ h^{-1}$)

Table 2 (continued)

Study	Study group	Weeks	Mean frequency (per week)	Total sessions	Small-sided games type	No. of sets	Set duration, min	Rest period, min	No. of players per team	Pitch length, m	Pitch width, m	Total dimensions, m^2	Goalkeepers	Exercise intensity	Test
Radziminski et al. [27]	Small-sided games	8	2	16	3 vs. 3, 3 vs. 3 with floating neutral player	5	4	3	3–4	30	18	540		90% HR max	Graded cycle test [VO_{2max} (mL kg^{-1} min^{-1})]
	Running	8	2	16		5	4	3						90% HR max	Graded cycle test [VO_{2max} (mL kg^{-1} min^{-1})]
Safania et al. [28]	Small sided games	6	3	18	2 vs. 2, 10 × 15 m; 3 vs. 3, 2–3 ball touches, 25 × 35 m field dimension; 4 vs. 4, 2 ball touches, 40 × 50 m field dimension	4	4	3	2–4				No	70–95% HR max	12-min running test [VO_{2max} (mL kg^{-1} min^{-1})]
	Interval training	6	3	18		4	4	3						70–95% HR max	12-min running test [VO_{2max} (mL kg^{-1} min^{-1})]

HR max maximum heart rate, *Vo2 max* maximal oxygen uptake

[a] Average set volume of 3.2

[b] Analysed as two sessions per week in subgroup analyses

75%, respectively; however, these thresholds are considered tentative [32]. The χ^2 (chi square) assesses if any observed differences in results are compatible with chance alone. A low *p* value, or a large Chi-squared statistic relative to its degree of freedom, provides evidence of heterogeneity of intervention effects beyond those attributed to chance [30].

2.4 Assessment of Risk of Bias

The Physiotherapy Evidence Database (PEDro) scale was used to assess the risk of bias and methodological quality of eligible studies included in the meta-analysis. This scale evaluates internal study validity on a scale from 0 (high risk of bias) to 10 (low risk of bias). A score of ≥ 6 represents the threshold for studies with a low risk of bias [33]. The articles were assessed by JM and HC and the agreed-upon ratings are presented in Table 3. For the assessment of publication bias, a funnel plot is presented in Fig. 2.

2.5 Analysis of Moderator Variables

To assess the potential effects of moderator variables, subgroup analyses were performed. This method was preferred to meta-regression based on documented limitations of the latter method when applied to small datasets with low sample sizes and few predictor variables [34].

Using a random-effects model, we selected potential moderators likely to influence the effects of training. Participants were divided using a median split for the following variables: age (≥ 15.7 years), height (≥ 174.0 cm), body mass (≤ 62.1 kg), total number of training sessions (≥ 16), mean number of sets per session (> 4), mean set duration (≥ 4 min) and mean recovery time between sets (≥ 3 min). Studies included in the programme duration subgroup (≥ 8 weeks) were divided on the basis that in previous work, neither maximal nor submaximal aerobic training variables were altered after 8 weeks of either sprint interval or continuous training in young boys [19]. Training frequency per week was divided into the following subgroups: 2 sessions or > 2 sessions per week, as these were the only possible classifications to make with the available data. For the calculation of ESs based on programming parameters, mean values for variables, such as set time, were used where necessary.

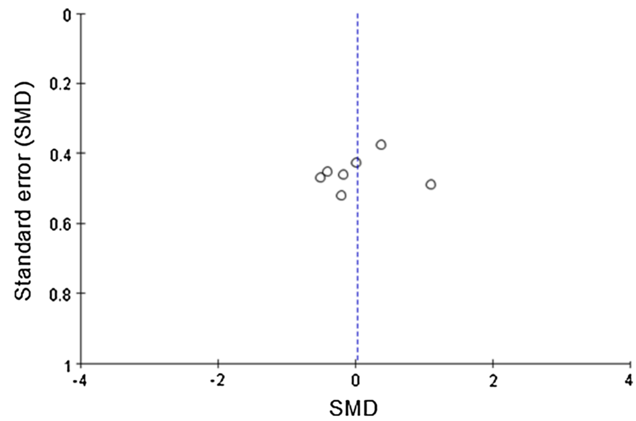


Fig. 2 Funnel plot of publication bias. *SMD* standardised mean difference

3 Results

3.1 Main Effect

Seven studies were included in this meta-analysis. There was a trivial between-mode ES [0.04 (95% CI – 0.36, 0.43), $Z=0.18$ ($p=0.86$)] in endurance performance that was not significant. The mean score of the included studies relating to risk of bias was 5.3. There was a non-significant level of between-study heterogeneity [$I^2=27\%$ ($p=0.22$)]. Within-mode ESs were both of moderate magnitude [SSG: 0.82 (95% CI 0.05, 1.60), $Z=2.07$ ($p=0.04$); CET: 0.89 (95% CI 0.06, 1.72), $Z=2.10$ ($p=0.04$)]. These results are displayed in Fig. 3 [SSG (a) vs. CET (b)] and Fig. 4 (baseline vs. follow-up).

Table 3 Physiotherapy Evidence Database (PEDro) scale ratings

Study	1[a]	2	3	4	5	6	7	8	9	10	11	Total
Eniseler et al. [23]	1	1	0	1	0	0	0	1	1	1	1	6
Hill-Haas et al. [24]	1	1	0	1	0	0	0	0	1	1	1	5
Impellizzeri et al. [20]	1	1	0	1	0	0	0	0	1	1	1	5
Jastrzebski et al. [25]	1	0	0	1	0	0	0	1	1	1	1	5
Los Arcos et al. [26]	1	1	0	1	0	1	0	1	1	1	1	7
Radziminski et al. [27]	1	1	0	1	0	0	0	0	1	1	1	5
Safania et al. [28]	1	0	0	0	0	0	0	1	1	1	1	4

[a]Item 1 is not used to calculate the final rating

Study or Subgroup	SSG Mean	SSG SD	SSG Total	CET Mean	CET SD	CET Total	Weight	Std. Mean Difference IV, Random, 95% CI
Eniseler et al. [23]	2,432	336	10	2,480	158.7	9	13.9%	-0.17 [-1.07, 0.73]
Hill-Haas et al. [24]	58.9	5.5	10	61.4	3.5	9	13.5%	-0.51 [-1.43, 0.41]
Impellizzeri et al. [20]	61.8	4.5	14	60.2	3.9	15	18.5%	0.37 [-0.37, 1.11]
Jastrzebski et al. [25]	57	5.44	11	56.9	5.58	11	15.5%	0.02 [-0.82, 0.85]
Los Arcos et al. [26]	16.9	0.8	7	17.1	1	8	11.6%	-0.21 [-1.22, 0.81]
Radziminski et al. [27]	63.3	8.04	9	55.3	6.07	11	12.7%	1.09 [0.13, 2.05]
Safania et al. [28]	42.89	1.42	10	43.48	1.38	10	14.2%	-0.40 [-1.29, 0.48]
Total (95% CI)			**71**			**73**	**100.0%**	**0.04 [-0.36, 0.43]**

Heterogeneity: Tau² = 0.07; Chi² = 8.19, df = 6 (P = 0.22); I² = 27%
Test for overall effect: Z = 0.18 (P = 0.86)

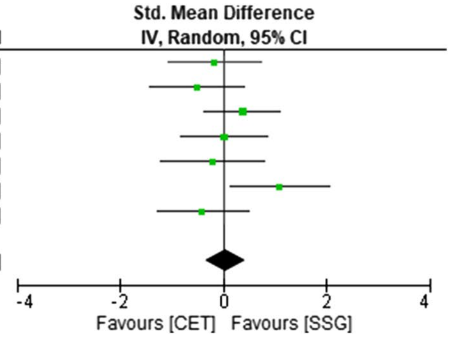
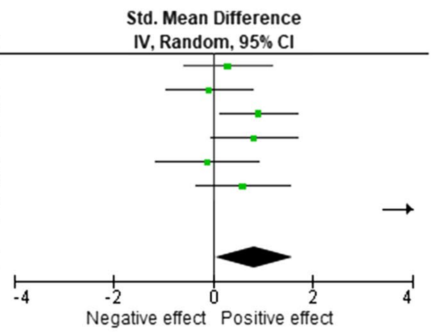


Fig. 3 Forest plot of between-mode effect sizes with 95% confidence intervals (CIs). *CET* conventional endurance training, *IV* inverse variance method, *SD* standard deviation, *SSG* small-sided games, *Std* standardised

a

Study or Subgroup	Post Mean	Post SD	Post Total	Pre Mean	Pre SD	Pre Total	Weight	Std. Mean Difference IV, Random, 95% CI
Eniseler et al. [23]	2,432	336	10	2,320	388	10	15.5%	0.30 [-0.59, 1.18]
Hill-Haas et al. [24]	58.9	5.5	10	59.3	4.5	10	15.5%	-0.08 [-0.95, 0.80]
Impellizzeri et al. [20]	61.8	4.5	14	57.7	4.2	14	16.1%	0.91 [0.13, 1.70]
Jastrzebski et al. [25]	57	5.44	11	52.5	5.15	11	15.5%	0.82 [-0.06, 1.69]
Los Arcos et al. [26]	16.9	0.8	7	17	0.8	7	14.3%	-0.12 [-1.17, 0.93]
Radziminski et al. [27]	63.3	8.04	9	58.6	6.93	9	15.0%	0.60 [-0.35, 1.55]
Safania et al. [28]	42.89	1.42	10	34.19	1.6	10	8.1%	5.51 [3.41, 7.61]
Total (95% CI)			**71**			**71**	**100.0%**	**0.82 [0.05, 1.60]**

Heterogeneity: Tau² = 0.82; Chi² = 26.44, df = 6 (P = 0.0002); I² = 77%
Test for overall effect: Z = 2.07 (P = 0.04)



b

Study or Subgroup	Post Mean	Post SD	Post Total	Pre Mean	Pre SD	Pre Total	Weight	Std. Mean Difference IV, Random, 95% CI
Eniseler et al. [23]	2,480	158.7	9	2,306.6	252.1	9	15.0%	0.78 [-0.18, 1.75]
Hill-Haas et al. [24]	61.4	3.5	9	60.2	4.6	9	15.2%	0.28 [-0.65, 1.21]
Impellizzeri et al. [20]	60.2	3.9	15	55.6	3.4	15	16.1%	1.22 [0.43, 2.01]
Jastrzebski et al. [25]	56.9	5.58	11	55.7	5.23	11	15.8%	0.21 [-0.63, 1.05]
Los Arcos et al. [26]	17.1	1	8	16.8	0.9	8	14.9%	0.30 [-0.69, 1.29]
Radziminski et al. [27]	55.3	6.07	11	56.2	8.67	11	15.8%	-0.12 [-0.95, 0.72]
Safania et al. [28]	43.48	1.38	10	33.96	1.38	10	7.2%	6.61 [4.16, 9.05]
Total (95% CI)			**73**			**73**	**100.0%**	**0.89 [0.06, 1.72]**

Heterogeneity: Tau² = 0.95; Chi² = 30.12, df = 6 (P < 0.0001); I² = 80%
Test for overall effect: Z = 2.10 (P = 0.04)

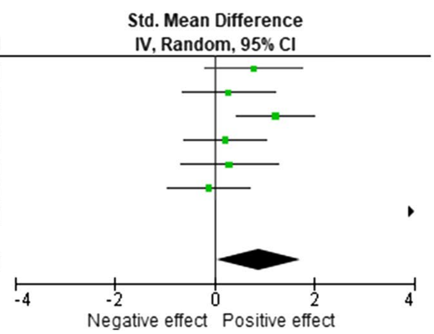


Fig. 4 Forest plot of within-mode effect sizes with 95% confidence intervals (CIs). *IV* inverse variance method, *SD* standard deviation, *Std* standardised

3.2 Effect of Moderator Variables

The subgroup analysis (Table 4) showed between-group heterogeneity ranging from low to high, demonstrating statistical significance in one case [number of weeks ($p=0.04$)]. Differences were trivial to small between each training type across subgroups. Programmes that were longer than 8 weeks had larger ESs in SSGs [ES = 0.45 (− 0.12, 1.02), $Z=1.54$ ($p=0.12$)], with the opposite being true for CET [ES = − 0.33 (95% CI − 0.79, 0.14), $Z=1.39$ ($p=0.16$)]. Programmes with more than 4 sets per session favoured SSGs [ES = 0.53 (95% CI − 0.52, 1.58) $Z=0.98$ ($p=0.33$)] with only a trivial difference between those with 4, or fewer, sets [ES = − 0.13 (95% CI − 0.52, 0.26), $Z=0.65$ ($p=0.52$)].

4 Discussion

The main findings of this meta-analysis indicate that SSGs can be used instead of, or in addition to, CET to target endurance performance in male youth soccer players. This has important implications for coaches because it means that male youth soccer players can develop endurance qualities and technical skills concurrently, thus representing a more time-efficient approach to training [35]. This

Table 4 Subgroup analyses

Outcome or subgroup	Studies, *n*	Participants, *n*	Estimated effect size, mean (95% CI)
Sets, *n*	7	144	
> 4	2	42	0.53 (– 0.52, 1.58)
≤ 4	5	102	– 0.13 (– 0.52, 0.26)
Set duration, min	7	144	
≥ 4	5	103	0.08 (– 0.49, 0.64)
< 4	2	41	– 0.07 (– 0.68, 0.54)
Recovery period between sets, min	7	144	
≥ 3	5	103	0.14 (– 0.37, 0.65)
< 3	2	41	– 0.22 (– 0.84, 0.40)
Weeks	7	144	
≥ 8	3	71	0.45 (– 0.12, 1.02)
< 8	4	73	– 0.33 (– 0.79, 0.14)
Frequency, per week	7	144	
> 2	1	20	– 0.40 (– 1.29, 0.48)
2	6	124	0.11 (– 0.32, 0.54)
Total sessions, *n*	7	144	
≥ 16	4	91	0.25 (– 0.32, 0.83)
< 16	3	53	– 0.30 (– 0.84, 0.24)
Age, y	7	144	
≥ 15.7	4	90	– 0.00 (– 0.42, 0.41)
< 15.7	3	54	0.12 (– 0.85, 1.10)
Height, cm	7	144	
≥ 174.0	4	85	0.05 (– 0.37, 0.48)
< 174.0	3	59	0.05 (– 0.95, 1.04)
Body mass, kg	7	144	
> 62.1	3	63	0.07 (– 0.43, 0.57)
≤ 62.1	4	81	0.04 (– 0.65, 0.72)

Positive effect size favours small-sided games

CI confidence interval

is favourable in comparison to the relatively one-dimensional nature of CET, which permits only the targeting of endurance performance. On that basis, overuse of CET could also add to a congested training schedule causing excessive physical stress which, in turn, can result in burnout and/or injury in youth players [36]. In addition, it is reported that CET is less enjoyable to youth soccer players compared with other training formats [37]. Previous evidence indicates that youth soccer players experience negative outcomes relating to physical performance [38] and hormonal profile [39] during periods of higher density training [15], which necessitates the careful balancing of workloads in the younger individual. Small-sided games can facilitate this balance by providing a multidimensional approach to addressing the diverse demands of soccer play [14]. However, coaches must be aware that the use of SSGs can increase the likelihood of sustaining contact-based injuries. In this way, CET can serve a purpose for players who are returning to play or who are in need of a volume of non-contact training time.

Whilst the within- and between-mode analyses both reveal SSG training and CET to be equally effective in enhancing endurance performance in male youth soccer players, some of the ESs seen in individual studies warrant further investigation. Jastrzebski et al. [25] found that SSGs exerted a moderate effect on performance whilst CET resulted only in a borderline trivial-small ES. The authors reported that both groups experienced similar changes in $\dot{V}O_{2max}$ but inspection of the ESs in our meta-analyses suggests that this was not the case [0.82 (SSG) vs. 0.21 (CET)]. Jastrzebski et al. [25] allude to performance increases as a result of SSG being related to the competitive nature of that type of activity, with this feature not necessarily being as important in CET. It is worth noting that previous evidence indicates that despite training heart rate responses being similar in both SSGs and CET, the latter training type seems to induce perceptions of higher intensity in players [24]. It is possible that this is an important factor in adaptations to SSGs with a lower perception of effort potentially resulting in a greater level of engagement with the training process. We tentatively suggest that neither players nor coaches would be as motivated to increase intensity in this manner when undertaking CET only.

In contrast to the findings of Jastrzebski et al. [25], Eniseler et al. [23] found larger effects with CET than they did in SSGs. The researchers speculated on a number of different potential explanations on the discrepancy in performances between the groups, the most compelling of which relates to the motivation of athletes to take full part in training. Though it seems that SSG training is preferable to CET from an enjoyment perspective [37], this does not necessarily guard against players taking voluntary rest periods during the course of the activity. Unlike CET, SSGs are inherently acyclic and unpredictable in format, meaning coaches must make extra efforts to keep players consistently involved in play. Reinforcing this is the previous finding that verbal encouragement seems to exert a clear and direct effect on the intensity of SSGs [40], underlining a coach's ability to influence player activity as, and when, required.

Subgroup analyses revealed similar findings to the main analysis with few differences observed for the effects of training when study cohorts were divided by age, stature or body mass. These findings are important in light of previous indications of a maturational threshold that moderates responses to training in youth, suggesting that less mature individuals may not adapt to the imposed demands of endurance exercise [41]. Albeit based on limited data and proxies (age, stature, body mass) of maturational status only, the current results indicate that SSGs are a favourable alternative to CET regardless of age or maturation status, meaning that coaches can effectively utilise the method across the maturational spectrum.

Further subgroup analyses of programming parameters also revealed some interesting findings. Interventions with more than 4 sets per session favoured SSGs. This would seem to indicate that SSG session volume and, by extension, overall training volume is an important factor in programming this type of exercise in youth soccer players. This result is reinforced by the finding that a higher overall load of sessions (≥ 16) favoured SSGs. Training volume is thought to be a key determinant of mitochondrial content, one of the primary adaptive responses to aerobic training [42]. This suggests coaches should place a high level of importance on this programming variable to ensure larger adaptations. However, it is vital that coaches temper their use of higher training volumes to avoid overtraining and overuse injury. Coaches should therefore prescribe an appropriate balance of work and recovery to ensure players can recuperate from the rigours of SSGs. On this point, training frequencies of more than two per week do not seem to favour SSGs, possibly because of the greater number of high-intensity movements, in comparison to CET, that have been reported in youth soccer [43].

Accordingly, SSGs, as used for the purposes of enhancing endurance performance, can be programmed up to two times per week with adequate recovery between bouts of activity. However, owing to the homogeneity of training frequencies used across studies, more research, utilising varying amounts of sessions per week, must be carried out to establish more robust recommendations for this parameter. Researchers are therefore encouraged to conduct studies examining the effects of one, three, four or more SSG sessions per week in youth soccer players.

A further finding of subgroup analyses is related to the duration of the SSG and CET programmes that were used in the included studies. Programmes that lasted 8 weeks or more seemed to favour SSG training whilst programmes carried out for a shorter period of time favoured CET. Based on these findings, coaches may have to expose youth players to longer SSG training interventions to elicit a comparable training response, possibly owing to the unpredictable player movement profiles associated with this type of activity. For example, it is possible that, as in traditional soccer play, players could self-regulate their activity levels during SSG training, increasing or decreasing their effort depending on the nature of the game itself and the unpredictability of in-play events. Increases in performance could therefore manifest quicker with the more focused approach of CET, but this method has the disadvantage that it does not necessarily support the development of technical soccer skills. This seems a plausible explanation for this result. Previous work that compared physiological responses to SSGs and CET in youth soccer players indicated differences across a number of endurance-related variables. Ade et al. [43] reported that speed endurance running drills induced higher heart-rate responses, blood lactate levels and ratings of perceived exertion than similarly configured SSGs. Moreover, total distance covered and high-intensity running distance were greater in running drills than in SSGs with the latter seemingly more effective in stimulating the development of the anaerobic energy system. If this was the case in the studies included in the current analyses, it could be that it takes a longer period of time for SSGs to adequately stimulate the underpinning factors that determine endurance performance in youth soccer players.

Related to this point, training intensity is difficult to control within SSGs but perhaps, given the similarity of adaptation to CET, does not need to be tightly controlled by coaches if training is carried out for an appropriate amount of time. As training volume (duration) was equated in the studies included in this meta-analysis, the findings suggest that intensity was also similar between the CET and SSG conditions, most particularly in relation to the main effect. Any other differences between SSGs and CET could be reflected by the type of endurance test used to measure the effects of the training intervention. For example, the greater the level of equivalence between the training method and the endurance test used, the more likely the test may reflect any changes in performance.

There are a number of limitations associated with this meta-analysis. The high number of moderator variables chosen can falsely increase the chances of positive findings [44], though these factors were determined a priori and are highly relevant to the analyses undertaken. Regardless, these recommendations must be viewed with caution as the dichotomisation of continuous data with a median split could result in residual confounding and reduced statistical power [45, 46]. This is further underlined by the low number of studies that qualified for this meta-analysis but the results can, nonetheless, be used to form a consensus on the effectiveness of SSGs for youth athletic development. Furthermore, few studies have reported performance measures (i.e. global positioning system data, fatigue index), and external validity is thus generally quite low. Future studies can further establish the variables that are of most importance for enhancing aerobic endurance performance in youth soccer players, whilst inter-individual responses [47] to SSG and CET should also be investigated. This supports a more focused approach to programming for endurance training whereby an individual can be exposed to the modality to which they respond best (i.e. SSGs vs. CET). It also remains unclear whether a combination of SSGs and CET would be a more effective training stimulus. Though the current data do not support it, as youth soccer players become fitter, they may need to be exposed to alternative or hybrid training modalities to continue to drive adaptations.

5 Conclusion

The findings of this meta-analysis suggest that SSGs can be used instead of, or in addition to, CET for the development of endurance in male youth soccer players. Indeed, it seems that CET may not be expressly required in youth because the same performance improvements can be achieved via the use of SSGs. This finding is further strengthened by other evidence that suggests SSGs can simultaneously target technical skill development, making it a more attractive training option than CET. If fitness qualities can be developed and maintained in a manner that keeps the individual engaged and exposes him/her to a wide variety of movement patterns and technical skills, several long-term athletic development goals can be targeted concurrently. This can increase athlete engagement whilst also reducing overall workloads as a result of enhanced training efficiency. Training programmes should be performed for an extended period of time (> 8 weeks) and should include 4 or more sets per session, 4 min per set and 3 min recovery between sets [48]. These training variables are in line with seminal recommendations for aerobic training in young soccer players [48] and are congruent with the results of our analyses. Despite this, our results are based on small sample sizes and more studies should be conducted to verify these recommendations.

Compliance with Ethical Standards

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