

Effects of Core Training Combined with Small-Sided Games on Physical Performance in Young Soccer Players: An 8-Week Randomized Trial

Genç Futbolcularda Dar Alan Oyunları ile Kombine Edilmiş Core Antrenmanının Fiziksel Performansa Etkisi: 8 Haftalık Randomize Çalışma

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ABSTRACT

The aim of this study was to compare the effects of 8-week core training alone versus core training combined with small-sided games on sprint, change of direction (COD), vertical jump (CMJ), repeated anaerobic sprint test (RAST), and intermittent aerobic endurance (30-15 VIFT) performance in young soccer players. Twenty-four male athletes (17.17 ± 0.48 years) competing in the TFF Development League U17 were randomly assigned to either the Core Training Group (CG; $n = 12$) or the Combined Core and Small-Sided Games Group (CCSSG; $n = 12$). Performance assessments included 10 m and 30 m sprint tests, the Illinois agility test, countermovement jump, the Running-Based Anaerobic Sprint Test for anaerobic power, the 30-15 Intermittent Fitness Test for maximal running speed (VIFT), estimated $\dot{V}O_{2max}$, and ratings of perceived exertion (RPE). Data were analyzed using a two-way mixed ANOVA. Both groups demonstrated significant improvements in sprint performance, countermovement jump height, and peak anaerobic power ($p < 0.05$). However, the combined training group showed significantly greater adaptations than the isolated core group in anaerobic power variables (peak, average, and minimum; $\eta^2 = 0.38-0.51$), VIFT ($p = 0.003$), estimated $\dot{V}O_{2max}$ ($p = 0.001$), and RPE responses ($p = 0.033$). Agility performance improved significantly only in the combined training group ($p = 0.038$). No significant time $\times$ group interactions were observed for sprint performance, countermovement jump, or fatigue index. Overall, although isolated core training elicited moderate performance gains, integrating core exercises with small-sided games resulted in superior improvements in anaerobic power and aerobic capacity, accompanied by higher perceived exertion responses, indicating that this combined approach may be more effective for holistic physical development in elite youth soccer players.

Keywords: Core training, small-sided games, anaerobic power, aerobic capacity, young soccer players.

ÖZET

Bu çalışmanın amacı, genç futbolcularda 8 haftalık core antrenmanı ile dar alan oyunlarıyla kombine edilmiş core antrenmanının sprint, yön değiştirme (COD), dikey sıçrama (CMJ), tekrarlı anaerobik sprint testi (RAST) ve aralıklı aerobik dayanıklılık (30-15 VIFT) performansları üzerindeki etkilerini karşılaştırmaktır. Türkiye Futbol Federasyonu Gelişim Ligi U17 kategorisinde mücadele eden yirmi dört erkek futbolcu ($17,17 \pm 0,48$ yıl), Core Antrenman Grubu'na (CG; $n = 12$) veya Kombine Core ve Dar Alan Oyunları Grubu'na (CCSSG; $n = 12$) rastgele atanmıştır. Performans değerlendirmeleri; 10 m ve 30 m sprint testleri, Illinois çeviklik testi, countermovement jump (CMJ), anaerobik güç için Running-Based Anaerobic Sprint Test (RAST), maksimal koşu hızı (VIFT) için 30-15 Intermittent Fitness Test, tahmini $\dot{V}O_{2max}$ ve algılanan zorluk derecesi (AZD) ölçümlerini içermiştir. Veriler two-way mixed ANOVA ile analiz edilmiştir. Her iki grup da sprint performansı, countermovement jump yüksekliği ve zirve anaerobik güçte anlamlı gelişmeler göstermiştir ($p < 0,05$). Bununla birlikte, kombine antrenman grubu anaerobik güç değişkenlerinde (zirve, ortalama ve minimum; $\eta^2 = 0,38-0,51$), VIFT'de ($p = 0,003$), tahmini $\dot{V}O_{2max}$ 'ta ($p = 0,001$) ve AZD yanıtlarında ($p = 0,033$) tek başına core antrenmanı grubuna kıyasla daha yüksek adaptasyonlar göstermiştir. Çeviklik performansı yalnızca kombine antrenman grubunda anlamlı düzeyde gelişmiştir ($p = 0,038$). Sprint performansı, countermovement jump ve yorgunluk indeksi açısından anlamlı zaman $\times$ grup etkileşimi bulunmamıştır. Sonuç olarak, tek başına uygulanan core antrenmanı orta düzeyde performans gelişimleri sağlarken, core egzersizlerinin dar alan oyunlarıyla birleştirilmesi anaerobik güç ve aerobik kapasitede daha üstün gelişimler sağlamış, buna daha yüksek algılanan zorlanma yanıtları eşlik etmiştir. Bu bulgular, söz konusu kombine yaklaşımın elit genç futbolcularda fiziksel gelişimin bütüncül olarak desteklenmesinde daha etkili olabileceğini göstermektedir.

Anahtar kelimeler: Core antrenmanı, Dar alan oyunları, Anaerobik güç, aerobik kapasite, genç futbolcular



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1. Introduction

Soccer is characterized by intermittent activity patterns involving repeated transitions between low-to-moderate intensity movements (e.g., walking and jogging) and high-intensity actions such as sprinting, acceleration, deceleration, jumping, and rapid changes of direction (Iaia et al., 2009; Buchheit & Laursen, 2013). Due to these complex physical demands, soccer players are required to simultaneously develop multiple physical capacities, including speed, agility, anaerobic power, and aerobic endurance (Stølen et al., 2005). Therefore, training methods that effectively replicate the physiological and movement-specific demands of match play are considered important for optimizing physical performance in young soccer players (Dellal et al., 2012; Clemente et al., 2014).

Among contemporary soccer training methods, small-sided games (SSGs) are widely used because they simultaneously stimulate technical, tactical, physiological, and neuromuscular adaptations under game-specific conditions (Clemente et al., 2014; Hammami et al., 2018; Moran et al., 2019). Previous studies have shown that SSG-based training can improve sprint performance, repeated sprint ability, aerobic fitness, agility, and soccer-specific movement efficiency in soccer players (Chaouachi et al., 2014; Owen et al., 2012; Clemente, 2020). In addition, the ability of soccer players to perform explosive and dynamic movements during matches is closely associated with muscular strength and neuromuscular readiness (Wisløff et al., 2004). Therefore, combining SSG-based training with strength-oriented approaches may provide a more comprehensive framework for improving soccer-specific physical performance (Güneralp et al., 2025; Kharatzadeh et al., 2025).

Core training has become an important component of soccer conditioning programs because of its role in trunk stabilization, force transmission, and neuromuscular control (Akuthota & Nadler, 2004; Behm et al., 2010). The core musculature surrounding the lumbopelvic-hip complex contributes to efficient force transfer between the lower and upper extremities during dynamic athletic movements (Boyacı & Bıyıklı, 2018). In addition, core stability facilitates the transfer of torque and angular momentum between body segments and may support explosive movement performance during soccer-specific activities (Granacher et al., 2014). Previous studies have reported that core-focused training may positively influence sprinting, jumping, balance, and agility performance in soccer players (Afyon et al., 2017; Sever & Zorba, 2018). Furthermore, core training supports the integration of the musculoskeletal and neuromuscular systems and may improve movement mechanics during high-intensity soccer actions (Behm et al., 2010; Frank et al., 2013).

Although the independent effects of SSGs and core training have been widely investigated, studies examining their combined effects on physical performance in youth soccer players remain limited. Current studies and systematic reviews have largely focused on combining SSGs with high-intensity interval training (HIIT), repeated sprint training (RST), and change-of-direction (COD) drills. However, research directly examining the integration of core training with SSG-based conditioning models remains scarce. In particular, direct comparisons between isolated core training and combined core + SSG training models using sport-specific performance tests are limited in youth soccer players. In a similar study, Arslan et al. (2021) reported that combining core strength exercises with SSG training produced greater improvements in selected physical performance parameters compared with isolated training approaches. However, further evidence is still needed to better understand the effectiveness of integrating core training with soccer-specific game-based conditioning models in youth soccer players.

Therefore, the aim of this study was to compare the effects of 8-week isolated core training and core training combined with small-sided games on sprint performance, change of direction (COD) ability, countermovement jump (CMJ), repeated anaerobic sprint performance (RAST), and intermittent aerobic endurance (30-15 VIFT) in young soccer players. It was hypothesized that the combined core and small-sided games training model would produce greater improvements in

inclusion criteria, three declined to participate, and one was excluded for other reasons), leaving 24 participants who were randomized. Final analyses were conducted on the Core Group (CG; $n = 12$) and the Combined Core and Small-Sided Games Group (CCSSG; $n = 12$). Participants had at least 3 years of licensed experience (mean age: $n = 24$; age: 17.17 ± 0.48 years; height: 1.72 ± 0.04 m; body mass: 65.31 ± 2.50 kg; BMI: 21.99 ± 0.47 kg/m²; body fat percentage: $8.60 \pm 0.36\%$; muscle mass: 55.78 ± 1.37 kg; training age: 6.12 ± 0.86 years) and followed a standardized schedule of five 90-minute sessions plus a weekend match. All participants and guardians provided written informed consent. The study adhered to the Declaration of Helsinki and was approved by the Atatürk University Ethics Committee (No: E-70400699-000-2500375963).

Physical Performance Testing

Participants were randomly assigned to the Core (CG) or Combined (CCSSG) group using permuted block randomization with allocation concealment via opaque, sealed envelopes. To ensure objectivity, training and assessments were supervised by a blinded performance coach. Measurements were conducted by the same researcher at the same time of day (15:00–17:00) under controlled conditions (24°C, 29% humidity) to minimize circadian effects. The test battery was completed over three sessions separated by 48-hour rest intervals, following a 10-minute standardized warm-up. The first session included 10-30m sprints and the Illinois agility test; the second session covered CMJ and RAST; and the third session consisted of the 30-15 VIFT. Familiarization sessions were conducted prior to baseline. For sprint, agility, CMJ, and RAST, the best of two trials was recorded, while VIFT was a single trial. Rest intervals were 3 minutes between trials and 5 minutes between tests. Standardization was maintained through identical equipment calibration, standardized verbal encouragement, and strict pre-test protocols (no heavy exercise or caffeine within 48 hours; last meal 3 hours prior). RAST and VO₂max values were calculated using automated software based on standard formulas. (Figure 2).

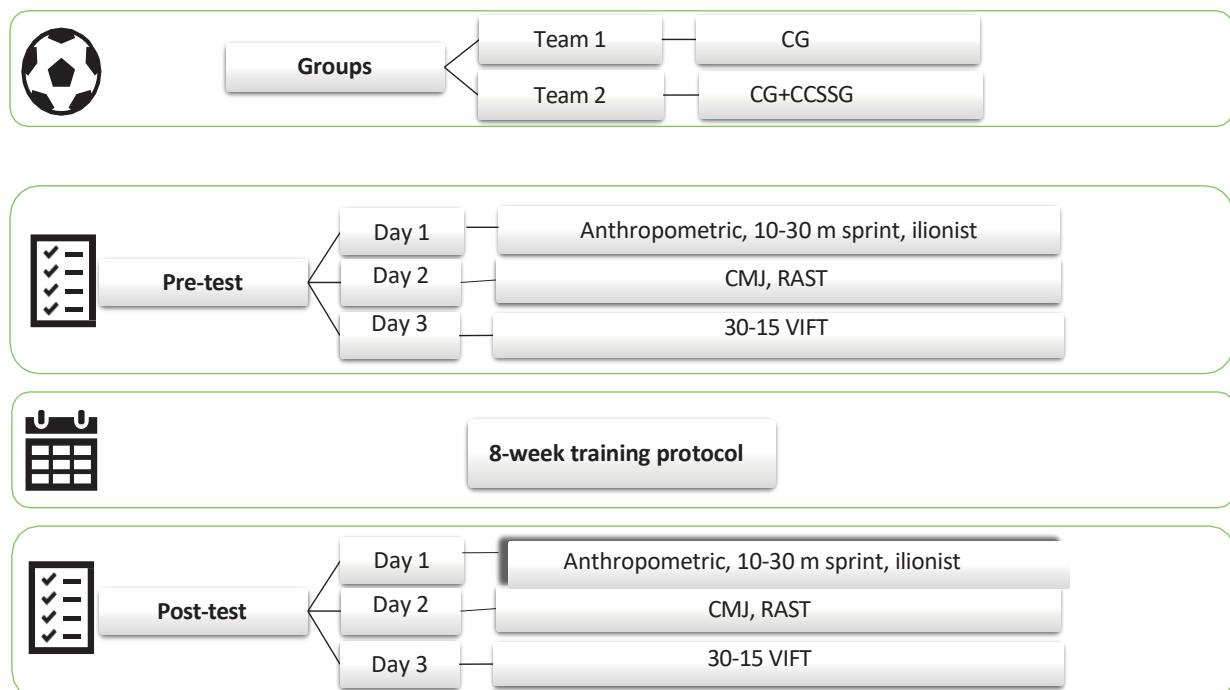


Figure 2. Core Group (CG) and Combined Core and Small-Sided Games Group (CCSSG) Test Protocol

Sprint Tests (10 m and 30 m)

In this study, 10-meter and 30-meter sprint tests were used to evaluate the short-distance sprint capacity of the participants. For each sprint test, participants started from a stationary standing position, with both feet just behind the starting line and the trunk upright. Upon an auditory signal, the sprint was initiated with maximum effort over the designated distance. Sprint times were recorded with millisecond precision using a dual-beam photocell system (Newtest 300 Series, Finland) positioned at the starting and finish lines.

Illinois Agility Test

The Illinois Agility Test is a widely used field-based assessment with high validity and reliability for measuring core components of agility, such as change-of-direction speed, acceleration, deceleration, and body control. A 10x5 meter course was marked with start and finish lines. The course was arranged with cones (a total of 4 cones) to create a template requiring changes of direction and sprinting. Athletes attempted to complete the course in the shortest possible time, starting with a sprint from the starting point. The running route included sprinting, backpedaling, changes of direction, and stop-and-start movements. The time taken to complete the test was recorded using a photocell timing system. Two trials were performed with a 3-minute rest between each, and the best score was included in the analysis.

Countermovement Jump (CMJ) Test

This test aimed to evaluate jump height and lower-extremity power. During the test, players stood with their feet shoulder-width apart and hands on their hips; after flexing their knees, they performed a maximal vertical jump. Two repetitions were completed with a 3-minute recovery, and the best score was recorded. In this study, a portable jump mat (Vald Performance, SmartJump, Brisbane, Australia) was used to measure vertical jump performance.

Running-based Anaerobic Sprint Test (RAST)

The Running-based Anaerobic Sprint Test (RAST) is a widely used intermittent test to assess anaerobic capacity in running-based sports. In this test, participants completed six 35-m sprints with 10 seconds of rest between each sprint. Following established methods, peak power (PP), average power (AP), minimum power (MP), and fatigue index (FI) were calculated (Zagatto et al., 2009). Power outputs were expressed in watts (W). The relevant formulas are as follows:

$$\text{Power (P)} = \frac{\text{weight} \times \text{distance}^2}{\text{time}^3}$$

$$\text{Power per weight (P/kg)} = \frac{P}{\text{weight (kg)}}$$

$$\text{Fatigue index} = (P_{\text{max}} - P_{\text{min}}) / \text{total time of the 6 sprints.}$$

30-15 Intermittent Fitness Test (VIFT)

The 30-15 Intermittent Fitness Test (VIFT) consists of 30-second shuttle runs separated by 15 seconds of passive recovery. The test began at 8 km/h, with running speed increasing by 0.5 km/h every 45 seconds. To account for direction changes, an empirical correction of 0.7 seconds was subtracted from each 30-second shuttle. Participants ran back and forth between two lines 40 m apart, guided by pre-recorded audio signals (30-15IFT app) to maintain the required speed. Safety zones of 3 m were positioned at the ends and center of the course. During the 15-second recovery, participants walked to the nearest starting line based on their position at the end of the previous shuttle.

The test continued until the participant failed to reach the safety zone three consecutive times. The final completed speed was recorded as the VIFT value (Buchheit et al., 2009). Estimated $\text{VO}_{2\text{max}}$ ($\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) was subsequently calculated from the final VIFT speed. Verbal encouragement was provided throughout to ensure maximal effort. Estimated $\text{VO}_{2\text{max}}$ Calculation

$$\text{VO}_{2\text{max}} (\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}) = 28.3 - (2.15 \times C) - (0.741 \times Y) - (0.0357 \times K) + (0.0586 \times Y \times H) + (1.03 \times H)$$

C = gender, Y = age (years), K = body mass (kg), and H = maximal VIFT speed ($\text{km} \cdot \text{h}^{-1}$).

Training Programs

The study lasted for 8 weeks, with the interventions integrated into regular soccer training sessions twice a week. Each training session began with a 10-minute warm-up (low-intensity running, dynamic stretching, and soccer-specific drills). Core Group (CG): This group performed core exercises twice a week for 8 weeks. The exercises were planned to focus on core stabilization in weeks 1 and 2, core endurance in weeks 3 and 4, core strength in weeks 5 and 6, and both core strength and endurance in weeks 7 and 8 (Table 1). After completing the core exercises, the group continued with their routine training plan (technical-tactical, etc.).

Combined Core and Small-Sided Games Group (CCSSG): This group performed additional small-sided games (SSG) after completing the core exercises. To ensure recovery, a 3-to-5-minute active rest period (light jogging and stretching) was implemented between the two training components before transitioning to the SSG sessions. The SSG training was conducted twice a week for 8 weeks in 6v6, 3v3, and 2v2 formats (Table 1). Different player numbers were utilized in the SSGs to provide various physical and tactical stimuli. While the 6v6 format focused more on tactical awareness and game flow, the 3v3 format targeted speed, agility, and anaerobic performance by increasing the number of sprints. The 2v2 format aimed to develop explosive power and quick decision-making by maximizing high-intensity movements and ball contacts per player. During the SSG sessions, heart rates were monitored using the Polar Team Pro System (Polar Electro, Kempele, Finland). After completing the SSG drills, the group continued with their routine training.

Table 1. The 8-week Core and SSG Training Program

CORE TRAINING PROGRAM			
1.-2. Week	3.-4. Week	5.-6. Week	7.-8. Week
Core Stabilization Number of Sets :3 reps Recovery:30 sec Recovery between:40 sec	Core Endurance Number of Sets :3 reps Recovery:30 sec Recovery between:40 sec	Core Strength Number of Sets :3 reps Recovery:30 sec Recovery between:40 sec	Core Strength and Endurance Number of Sets :3 reps Recovery:30 sec Recovery between:40 sec
1.Plank (30 sec) 2.Side Plank (30 sec bilaterally) 3.Bird-Dog (10 sec bilaterally) 4.Plank Shoulder Taps (10 reps bilaterally) 5.Glute Bridge (10 reps) 6.Dead Bug (10 reps bilaterally) 7.Superman (10 reps) 8.Hollow Body Hold (30 sec) 9. Quadruped Rocking (10 reps) 10. Side-Lying Windmill (10 reps bilaterally) 11.Bridge with Leg Extension (10 reps bilaterally) 12.Plank with to Elbow (10 reps bilaterally)	1.Mountain Climber (15 reps) 2.Russian Twist (15 reps) 3.Bicycle Crunch (15 reps) 4.Plank Hip Dips (15 reps) 5.Leg Raises (15 reps) 6.Flutter Kicks 7.V-Ups (10 reps) 8.Side Plank Hold with Leg Lift (10 reps) 9. Hollow Hold (30 sec) 10. Plank with Arm Reach (10 reps) 11.Seated Knee Tuck (10 reps) 12.Reverse Plank Hold (30 sec)	1.Palof press with band (10 reps) 2. Plank with Rotation (10 reps) 3.Russian twists with dumbbell (15 reps) 4.Medicine Ball Slam (10 reps) 5.Weighted Crunch (10 reps) 6.Kettlebell Swing (10 reps) 7.Medicine Ball Slams (10 reps) 8. Hanging Leg Raise (12 reps) 9. Side Plank with Hip Dip (10 reps bilaterally) 10. Bird Dog with Resistance Band (10 reps hbilaterally) 11.Forearm Plank with Shoulder Tap (10 reps bilaterally) 12.Dead Bug with Bodyweight (10 reps)	1.Resistance band seated row (15 reps) 2. Plank with Resistance Band Pull (10 reps) 3. Push-ups with Ball Pass (10 reps) 4.Resistance Band Squat (15 reps) 5.Resistance Band Glute Bridge (20 reps) 6.Resistance Band Walk Lunges (15 reps) 7.Resistance Band Lateral Walk lunges (20 reps) 8. Resistance Band Deadlift (15 reps) 9. Resistance Band Side Plank with Row (10 sec bilaterally) 10.Resistance Band Overhead Press (15 reps) 11.Resistence Band Step-Up with Knee Lift (15 reps bilaterally) 12. Resistance Band Mountain Climbers (20reps)
3-5 Min. Active Recovery			

SSG TRAINING PROGRAM				
Variables	1.-2. Week	3.-4. Week	5.-6. Week	7.-8. Week
SSG Formats	6v6	6v6	3v3	2v2
Pitch size (mxm)	35x40	35x40	20x30	16x20
Duration (min)	4	4	6	8
Bouts	3	4	4	4
Training Intensity (HRmax%)	%70-80	%70-80	%75-85	%80-90
Recovery Intensity (HRmax%)	%55-65	%55-65	%60-70	%60-70

Statistical Analysis

Statistical analysis of the data was performed using IBM SPSS Statistics software, version 26.0 (IBM Corp., Armonk, NY). Normal distribution of the data was verified using the Shapiro-Wilk test and Skewness-Kurtosis coefficients (within ± 1.5). Homogeneity of variances was confirmed via Levene's test, and all variables were found to be homogeneously distributed ($p > 0.05$). To determine the main effects of the training interventions (Group and Time) and the Group $\times$ Time interaction, a Two-Way Mixed Measures ANOVA was applied. Model-based post-hoc comparisons (with Bonferroni adjustment) were utilized to identify inter-group differences and intra-group changes (simple main effects). In addition to statistical significance, effect size coefficients and 95% confidence intervals (95% CI) were calculated to determine the magnitude of differences. Partial Eta Squared (η^2) was used for the Time $\times$ Group interaction, with values classified as 0.01 (small), 0.06 (medium), and 0.14 (large). To evaluate the magnitude of intra-group changes, Cohen's d effect size was calculated and interpreted according to the following criteria: < 0.20 (trivial), 0.20–0.50 (small), 0.50–0.80 (moderate), and > 0.80 (large) (Hopkins et al., 2009). For all analyses, the statistical significance level was set at $p < 0.05$.

3. Results

Table 2. Demographic characteristics of the participants.

Variables	Group	N	$\bar{X}$	SD	t	df	p
Age (years)	Core	12	17.175	0.499	-0.042	22	0.966
	CCSSG	12	17.183	0.460			
Height (m)	Core	12	1.7292	0.041	0.705	22	0.488
	CCSSG	12	1.7175	0.039			
Body mass (kg)	Core	12	65.358	2.239	0.089	22	0.930
	CCSSG	12	65.266	2.762			
BMI (kg/m ²)	Core	12	21.865	0.572	1.281	22	0.214
	CCSSG	12	22.119	0.375			
Body fat%	Core	12	8.6333	0.422	0.328	22	0.746
	CCSSG	12	8.5833	0.315			
Training age (year)	Core	12	6.1667	0.937	0.235	22	0.816
	CCSSG	12	6.0833	0.792			

Examination of Table 2 reveals that the demographic characteristics of the soccer players in the Core Group (CG) and Combined Core and Small-Sided Games Group (CCSSG) showed no statistically significant differences in age ($t = -0.042$, $p = 0.966$), height ($t = 0.705$, $p = 0.488$), body

mass ($t = 0.089$, $p = 0.930$), BMI ($t = 1.281$, $p = 0.214$), body fat percentage ($t = 0.328$, $p = 0.746$) and training periods ($t = 0.235$, $p = 0.816$) (all $p > 0.05$).

Table 3. Comparison of physical performance parameters, percentage changes, and effect sizes between training groups

Variables	CG (n=12)			CCSSG Group (n=12)				Between Groups		
	Pre Test	Post Test	%Δ	Within Group	Pre Test	Post Test	%Δ	Within Group	Time	Interaction
	$\bar{X} \pm SS$			p [d] Effect	$\bar{X} \pm SS$			p [d] Effect	p [η_p^2] Effect	p [η_p^2] Effect
10m (sec)	1.90 ± 0.26	1.84 ± 0.24	-3.15	0.042* [0.24] Small	2.02 ± 0.26	1.91 ± 0.24	-5.44	0.002* [0.44] Small	0.000* [0.63] Large	0.153 [0.09] Medium
30m (sec)	4.43 ± 0.40	4.29 ± 0.39	-3.16	0.041* [0.35] Small	4.63 ± 0.32	4.43 ± 0.24	-4.31	0.001* [0.71] Medium	0.000* [0.57] Large	0.374 [0.04] Small
Illinois (sec)	17.65 ± 0.88	17.43 ± 0.88	-1.24	0.125 [0.25] Small	17.90 ± 0.89	17.51 ± 0.89	-2.17	0.038* [0.43] Small	0.000* [0.56] Large	0.142 [0.10] Medium
CMJ (cm)	36.17 ± 1.85	37.58 ± 1.62	3.90	0.000* [0.81] Large	35.83 ± 2.08	37.17 ± 1.70	3.74	0.000* [0.70] Medium	0.000* [0.56] Large	0.490 [0.02] Small
RAST PP (W)	621.8 ± 94.9	638.2 ± 90.8	2.64	0.000* [0.18] Trivial	617.7 ± 85.8	670.4 ± 86.7	8.53	0.000* [0.61] Medium	0.000* [0.79] Large	0.000* [0.51] Large
Rast AP (W)	443.8 ± 72.4	451.6 ± 65.6	1.75	0.086 [0.11] Trivial	438.3 ± 53.1	473.9 ± 50.4	8.12	0.000* [0.69] Medium	0.000* [0.61] Large	0.001* [0.39] Large
Rast MP (W)	265.8 ± 51.9	265.0 ± 41.9	-0.30	0.919 [0.02] Trivial	260.1 ± 24.0	294.9 ± 37.5	13.42	0.000* [1.11] Large	0.005* [0.36] Large	0.001* [0.38] Large
Rast FI(W·s ⁻¹)	10.33±1.91	11.10±2.10	7.40	0.010* [0.89] Large	10.20±2.26	11.00±2.10	7.91	0.004* [1.031] Large	0.000* [0.502] Large	0.902 [0.001] Small
RAST Total time (sec)	34.77±2.07	33.93±1.96	-2.42	0.000* [1.54] Large	35.32±1.31	34.39±1.58	-2.63	0.000* [1.459] Large	0.000* [0.709] Large	0.723 [0.006] Small
30-15 IFT V _{IFT} (km/h)	17.97±0.44	18.06±0.44	+0.51	0.144 [0.45] Trivial	17.88±0.29	18.20±0.31	1.75	0.001* [2.671] Large	0.000* [0.620] Large	0.003* [0.328] Large
VO ₂ max (ml·kg ⁻¹ ·min ⁻¹)	49.83 ± 0.97	50.01 ± 0.95	0.37	0.166 [0.19] Trivial	49.62 ± 0.56	50.37 ± 0.58	1.50	0.000* [1.31] Large	0.003* [0.66] Large	0.001* [0.41] Large
RPE	17.08±0.79	17.25±0.75	0.99	0.166 [0.42] Small	16.91±0.66	17.75±0.75	4.96	0.010* [0.889] Large	0.002* [0.346] Medium	0.033* [0.190] Medium

$\bar{X} \pm SD$: Mean $\pm$ Standard Deviation; d: Cohen's d effect size; p^b : Significance of the main effect of time; η_p^2 (Time): Partial eta squared value for the time effect; p^c : Time $\times$ Group interaction significance (mixed ANOVA); η_p^2 (Int.): Partial eta squared value for the interaction effect.

A total of 24 young male soccer players successfully completed the 8-week training program along with the pre- and post-test procedures without any dropouts (CG: $n = 12$; CCSSG Grubu: $n = 12$). A comprehensive summary of the within-group and between-group pre-test and post-test values, statistical significance levels, and effect sizes for all performance parameters and related tests is presented in Table 3.

10m-30m Sprint Performance results

Significant improvements in sprint performance from pre- to post-test were observed in both groups. The CG showed a significant reduction in 10 m sprint time from 1.90 ± 0.26 s to 1.84 ± 0.24 s ($p = 0.042$, $d = 0.24$) and in 30 m sprint time from 4.43 ± 0.40 s to 4.29 ± 0.39 s ($p = 0.041$, $d = 0.35$). Similarly, the CCSSG group demonstrated significant improvements in 10 m sprint time (from 2.02 ± 0.26 s to 1.91 ± 0.24 s; $p = 0.002$, $d = 0.44$) and 30 m sprint time (from 4.63 ± 0.32 s to 4.43 ± 0.24 s; $p = 0.001$, $d = 0.71$). A two-way mixed-design repeated measures ANOVA (Time $\times$ Group) revealed a large and significant main effect of time for both 10 m sprint performance ($p < 0.001$, $\eta^2p = 0.63$) and 30 m sprint performance ($p < 0.001$, $\eta^2p = 0.57$), indicating substantial overall improvements across the intervention period in both groups. However, the Time $\times$ Group interaction was not statistically significant for either distance (10 m: $p = 0.153$, $\eta^2p = 0.09$; 30 m: $p = 0.374$, $\eta^2p = 0.04$), suggesting that the magnitude of improvement did not differ significantly between the CG and the CCSSG Group. Both groups demonstrated comparable improvements in sprint performance over the intervention period.

Illinois Agility Test results

No statistically significant improvement in Illinois agility test performance was observed in the Core Group (CG) from pre-test (17.65 ± 0.88 s) to post-test (17.43 ± 0.88 s; $p = 0.125$, $d = 0.25$; small effect size). In contrast, the CCSSG demonstrated a statistically significant improvement, with agility time decreasing from 17.90 ± 0.89 s to 17.51 ± 0.89 s ($p = 0.038$, $d = 0.43$; small effect size). A two-way mixed-design repeated measures ANOVA (Time $\times$ Group) revealed a large and significant main effect of time ($p < 0.001$, $\eta^2p = 0.56$), indicating substantial overall improvement in Illinois agility performance across the intervention period in both groups combined. However, the Time $\times$ Group interaction was not statistically significant ($p = 0.142$, $\eta^2p = 0.10$; medium effect size), suggesting that the magnitude of improvement did not differ significantly between the CG and the CCSSG. Although only the CCSSG group demonstrated a statistically significant within-group improvement, the non-significant Time $\times$ Group interaction indicates that the magnitude of change did not differ significantly between groups.

Countermovement Jump (CMJ) Performance results

Significant improvements in countermovement jump (CMJ) height were observed from pre- to post-test in both groups. The CG showed a statistically significant increase from 36.17 ± 1.85 cm to 37.58 ± 1.62 cm ($p < 0.001$, $d = 0.81$; large effect size). Similarly, the CCSSG group demonstrated a significant improvement, with CMJ height increasing from 35.83 ± 1.62 cm to 37.17 ± 1.62 cm ($p < 0.001$, $d = 0.70$; medium effect size). A two-way mixed-design repeated measures ANOVA (Time $\times$ Group) revealed a large and significant main effect of time ($p < 0.001$, $\eta^2p = 0.56$), indicating substantial overall improvement in CMJ performance across the intervention period in both groups combined. However, the Time $\times$ Group interaction was not statistically significant ($p = 0.490$, $\eta^2p = 0.02$; small effect size), suggesting that the magnitude of improvement did not differ significantly between the CG and the CCSSG Group.

Running-based Anaerobic Sprint Test (RAST) Results

Significant improvements were observed in several RAST parameters from pre- to post-test in both

groups. Peak Power (PP): The CG showed a statistically significant increase from 621.8 ± 94.9 W to 638.2 ± 90.8 W ($p < 0.001$, $d = 0.18$; trivial effect size). Similarly, the CCSSG demonstrated a significant improvement from 617.7 ± 85.8 W to 670.4 ± 86.7 W ($p < 0.001$, $d = 0.61$; medium effect size). Average Power (AP): No significant change was found in the CG (from 443.8 ± 72.4 W to 451.6 ± 65.6 W; $p = 0.086$, $d = 0.11$; trivial effect size). In contrast, the CCSSG group exhibited a significant increase (from 438.3 ± 53.1 W to 473.9 ± 50.4 W; $p < 0.001$, $d = 0.69$; medium effect size). Minimum Power (MP): No significant change was observed in the CG (from 265.8 ± 51.9 W to 265.0 ± 41.9 W; $p = 0.919$, $d = 0.02$; trivial effect size). However, the CCSSG group showed a statistically significant increase (from 260.1 ± 24.0 W to 294.9 ± 37.5 W; $p < 0.001$, $d = 1.11$; large effect size). A two-way mixed-design repeated measures ANOVA (Time $\times$ Group) revealed significant Time $\times$ Group interactions for peak power ($p < 0.001$, $\eta^2p = 0.51$; large effect size), average power ($p = 0.001$, $\eta^2p = 0.39$; large effect size), and minimum power ($p = 0.001$, $\eta^2p = 0.38$; large effect size), indicating that the magnitude of improvement in these anaerobic power variables was statistically significantly greater in the CCSSG group compared to the CG.

Fatigue Index (FI) and Total Time: Both groups exhibited a significant increase in the fatigue index (worsening) and a significant decrease in total time (improvement). However, the Time $\times$ Group interaction was not statistically significant for either the fatigue index ($p = 0.902$) or total time ($p = 0.723$), suggesting that the two groups showed comparable changes in these parameters.

30-15 Intermittent Fitness Test (V_{IFT}) Results

V_{IFT} (km/h): No statistically significant difference was observed in the CG between pre-test (17.97 ± 0.44 km/h) and post-test (18.06 ± 0.44 km/h) values ($p = 0.144$, $d = 0.45$). In contrast, the CCSSG group showed a statistically significant improvement, with V_{IFT} increasing from 17.88 ± 0.29 km/h to 18.20 ± 0.31 km/h ($p = 0.001$, $d = 2.671$). A two-way mixed-design repeated measures ANOVA (Time $\times$ Group) revealed a statistically significant Time $\times$ Group interaction ($p = 0.003$, $\eta^2p = 0.328$), indicating that the magnitude of improvement in V_{IFT} differed significantly between the two groups. The effect size for this interaction was medium-to-large ($\eta^2p = 0.328$).

VO₂max (ml $\cdot$ kg⁻¹ $\cdot$ min⁻¹): No significant change was found in the CG between pre-test (49.83 ± 0.97 ml/kg/min) and post-test (50.01 ± 0.95 ml/kg/min) values ($p = 0.166$, $d = 0.19$; trivial effect size). In contrast, the CCSSG group demonstrated a statistically significant increase from 49.62 ± 0.56 ml/kg/min to 50.37 ± 0.58 ml/kg/min ($p < 0.001$, $d = 1.31$; large effect size).

The mixed ANOVA showed a large and significant main effect of time ($p = 0.003$, $\eta^2p = 0.66$), indicating overall improvement in VO₂max across the intervention period. More importantly, the Time $\times$ Group interaction was also statistically significant ($p = 0.001$, $\eta^2p = 0.41$; large effect size), confirming that the improvement in aerobic capacity was significantly greater in the CCSSG Group compared to the CG.

Rating of Perceived Exertion (RPE): A small increase in RPE was observed in the CG from pre-test (17.08 ± 0.21) to post-test (17.25 ± 0.21). The CCSSG group also demonstrated an increase in RPE, from 16.91 ± 0.21 to 17.75 ± 0.21 . The Time $\times$ Group interaction was statistically significant ($p = 0.033$), with a medium effect size ($\eta^2p = 0.190$), indicating that the change in perceived exertion over time differed significantly between the two groups.

4. Discussion

The purpose of this study was to compare the effects of two different 8-week training models— isolated core training and combined core training with small-sided games (CCSSG)—on selected physical performance parameters (sprint, agility, CMJ, anaerobic, aerobic, and RPE) in young soccer players. The results indicate that both core exercises and SSG training positively influence various performance parameters in young soccer players, with the combination of core training and SSG demonstrating additional adaptations in selected performance parameters.

In the present study, the Core Group (CG) showed significant reductions in 10 m sprint time (from 1.90 s to 1.84 s; $p = 0.042$) and 30 m sprint time (from 4.43 s to 4.29 s; $p = 0.041$) from pre- to post-test. Similarly, the CCSSG group exhibited significant improvements in both 10 m (from 2.02 s to 1.91 s; $p = 0.002$) and 30 m sprint times (from 4.63 s to 4.43 s; $p = 0.001$). Between-group comparisons revealed large and significant main effects of time for both 10 m ($\eta^2p = 0.63$) and 30 m ($\eta^2p = 0.57$) sprint performance, indicating substantial overall sprint improvements across the intervention. However, the Time $\times$ Group interaction was not statistically significant for either distance (10 m: $\eta^2p = 0.09$; 30 m: $\eta^2p = 0.04$). Despite this, the CCSSG group demonstrated numerically superior percentage improvements (-5.44% in 10 m and -4.31% in 30 m) compared to the CG.

These findings demonstrate that both isolated core training and combined core + SSG training are effective in enhancing 10 m and 30 m sprint performance in young soccer players. Although the CCSSG group demonstrated numerically greater percentage improvements, the non-significant interaction effects indicate that sprint adaptations were generally comparable between groups. Literature supports the positive effects of core training on sprint performance (Mendes, 2016; Imai et al., 2014; Sever & Zorba, 2018), likely due to improved core stability optimizing the transfer of lower-limb force and enhancing running mechanics. Regarding SSG, studies highlight its positive impact on neuromuscular efficiency and sprint mechanics (Dello Iacono et al., 2021). Chaouachi et al. (2014) reported significant improvements in 15 m and 30 m sprint performance following 6 weeks of SSG (1v1, 2v2, and 3v3 formats). Similarly, Owen et al. (2012) found that a 4-week SSG protocol positively affected sprint performance. The inherent demands of SSG for rapid acceleration and deceleration may contribute positively to sprint-related adaptations (Rahmoune et al., 2025). Our results align with recent studies emphasizing game-based SSG models for sprint-related adaptations and suggest that integrating core exercises with SSG may provide an additional sport-specific training stimulus for sprint development in young soccer players.

The numerically greater percentage improvements observed in the CCSSG group may be associated with the combined application of core stability exercises and the dynamic, high-intensity loading characteristics of SSG. Similar field-based studies combining SSG with core strength training have reported moderate to large improvements, particularly in 5 m and 10 m sprint performance (Arslan et al., 2021). These findings may indicate that combining core exercises with SSG contributes positively to sprint-related performance adaptations in young soccer players.

Illinois Agility Performance

In the present study, examination of Illinois agility performance revealed no statistically significant difference in the Core Group (CG) between pre-test (17.65 ± 0.88 s) and post-test (17.43 ± 0.88 s) values ($p = 0.125$, $d = 0.25$; small effect size). In contrast, the Combined Core and Small-Sided Games Group (CCSSG) demonstrated a statistically significant improvement in agility time (from 17.90 ± 0.89 s to 17.51 ± 0.89 s; $p = 0.038$, $d = 0.43$; small effect size).

The literature supports the notion that core training facilitates efficient force transfer between the upper and lower body, thereby enhancing agility (Dos'Santos & Jones, 2022). This relationship between fundamental strength and agility is particularly critical in sports requiring rapid and multi-directional movements (Brull-Muria & Beltran-Garrido, 2021). Consistent with our findings, previous studies have reported benefits of core training on agility when applied three times per week (Doganay et al., 2020) and significant improvements in agility performance (measured via Illinois Agility Test and T-Drill) in amateur players following an 8-week protocol (Afyon et al., 2017; Sever & Zorba, 2018). The lack of statistical significance in the isolated core training group (CG) in our study may be attributable to the participants' baseline performance levels.

Regarding small-sided games (SSG), these activities involve smaller playing areas compared to full matches, forcing players to perform a high number of rapid changes of direction, accelerations,

and decelerations (Clemente, 2020). Chaouachi et al. (2014) demonstrated that while isolated running groups performed better in non-specific change-of-direction tests, SSG groups exhibited superior performance in sport-specific agility tasks. Similarly, Arslan et al. (2020) confirmed that SSG training may contribute positively to agility development.

Although the Time $\times$ Group interaction was not statistically significant ($p = 0.142$), the CCSSG group demonstrated numerically greater percentage improvements (CG: -1.24% vs. CCSSG: -2.17%) in agility performance. However, these findings should be interpreted cautiously due to the non-significant interaction effect. The dynamic and sport-specific movement demands of SSG, combined with trunk stabilization provided by core exercises, may contribute positively to agility-related adaptations in young soccer players.

Countermovement Jump (CMJ) Performance

According to the findings of the present study, both the Core Group (CG) and the Combined Core and Small-Sided Games Group (CCSSG) produced statistically significant improvements in countermovement jump (CMJ) performance among young soccer players ($p < 0.001$). The observed increase in both groups demonstrates that the training programs effectively stimulated explosive power qualities.

Literature review supports these results, with several studies reporting that core training leads to significant enhancements in vertical jump performance in soccer players (Boyacı & Afyon, 2017; Dilber et al., 2016). Similarly, Hoshikawa et al. (2013) highlighted that core training increases countermovement jump height in young athletes, consistent with our observations. It is proposed that improved core stability facilitates more efficient force transfer from the lower extremities through the trunk during vertical jumping. In this context, studies reporting a strong correlation between core performance and vertical jump ability (Nesser et al., 2008), as well as those recommending the addition of core training to field-based sessions for enhanced benefits (Prieske et al., 2016), are in full agreement with our findings. However, Göktepe et al. (2019) observed an increase in jump performance following 8 weeks of core training, but this improvement did not reach statistical significance, differing from our results.

Considering the comparable improvements observed in both groups, previous studies investigating combined training approaches have reported positive effects of integrating SSG with core training on CMJ performance. Arslan et al. (2021) reported that a group performing SSG combined with core training achieved a 11.4% improvement in CMJ performance over 6 weeks, compared to a 7.7% gain in a group performing SSG alone. However, the absence of a statistically significant between-group difference in the present study ($p = 0.490$, $\eta^2p = 0.02$) suggests that CMJ adaptations were generally comparable between groups.

Anaerobic Performance (RAST)

The RAST findings from the present study demonstrate that both isolated core training (CG) and combined core training with small-sided games (CCSSG) exert different degrees of influence on anaerobic performance components. Notably, the CCSSG group exhibited statistically significantly greater improvements in peak power (PP), average power (AP), and minimum power (MP) compared to the CG ($p < 0.05$; large effect sizes), indicating greater improvements in anaerobic power-related variables following the combined training model.

Literature reveals conflicting results regarding the impact of core training on anaerobic power. Başandaç (2022), in a 9-week study with elite athletes, reported that core stabilization exercises significantly increased peak and average power, supporting the PP improvements observed in our CG. In contrast, Mendes (2016) argued that 6 weeks of isolated core training alone had no effect on anaerobic power performance. The lack of significant changes in AP and MP in our CG ($p > 0.05$) suggests that anaerobic power may require more dynamic, sport-specific loading beyond static core

exercises.

The greater improvements observed in the CCSSG group may be associated with the additional high-intensity and sport-specific demands of SSG. Numerous studies emphasize the effectiveness of small-sided games (SSG) in improving anaerobic endurance and fatigue resistance (Umam & Suherman, 2023). Akyuz and Camlıguney (2025) reported substantial anaerobic performance gains following 8 weeks of SSG, with no significant change in fatigue index, paralleling our CCSSG findings ($p = 0.902$ for the interaction). The increase observed in minimum power (MP) in the CCSSG group (+13.42%; $d = 1.11$) may indicate that integrating core exercises with SSG contributes positively to repeated high-intensity performance capacity.

The similar changes in fatigue index (FI) and total time across both groups indicate that neither intervention produced a differential effect on these variables. Importantly, FI increased significantly in both groups, indicating greater fatigue, while the Time $\times$ Group interaction was not significant. In contrast to previous studies reporting reductions in fatigue index following SSG-based protocols, the present study observed increases in FI in both groups, with no significant Time $\times$ Group interaction. Therefore, the effects of the present interventions on fatigue resistance remain unclear and should be interpreted cautiously.

Aerobic Capacity (30-15 IFT and VO₂max) and RPE

One of the most notable findings of the present study was the significantly greater improvement in endurance-related parameters—30-15 Intermittent Fitness Test final speed (V_IFT) and estimated VO₂max—in the Combined Core and Small-Sided Games Group (CCSSG) compared to the Core Group (CG) ($p < 0.05$). The large and significant Time $\times$ Group interactions for both V_IFT ($\eta^2p = 0.328$) and VO₂max ($\eta^2p = 0.41$) indicate that the combined training model was associated with greater improvements in aerobic-related parameters compared to isolated core training.

A robust VO₂max capacity is known to facilitate oxygen delivery to active muscle tissue, thereby supporting metabolic processes during matches (Al-Asiri & Shaheen, 2015). Exercise program design is a critical determinant of success in this regard (Aziz et al., 2023). Reed et al. (2012) reported that abdominal muscle exercises contribute to muscular strength but do not improve VO₂max, which aligns with the non-significant changes in VO₂max ($d = 0.19$) and V_IFT observed in our CG. These results indicate that isolated core training enhances trunk stability but may not provide sufficient cardiovascular stimulus to substantially improve aerobic capacity.

In contrast, the effectiveness of SSG in improving aerobic capacity and VO₂max is well-supported in the literature (Maujud et al., 2021). Hammami et al. (2018) and Dellal (2012b) emphasized that SSG elicits heart rates of 80–90% of maximum (HRmax), providing match-like intensity. The higher RPE responses observed in the CCSSG group ($p = 0.033$; $\eta^2p = 0.190$) may reflect the greater perceived demands associated with the combined training sessions rather than a direct indicator of performance enhancement. Kusuma and Kardiawan (2018) argued that the high number of ball contacts in SSG may contribute positively to VO₂max development.

The large effect sizes obtained in our study ($d = 2.67$ for V_IFT; $d = 1.31$ for VO₂max) suggest that integrating core stability exercises with the high-intensity cardiovascular demands of SSG may contribute positively to aerobic performance development in young soccer players. These findings support the potential effectiveness of combining core exercises with soccer-specific high-intensity training activities for aerobic development in youth soccer players.

5. Conclusion

Both core training and combined core + small-sided games (CCSSG) training improved selected physical performance outcomes in young soccer players. However, the combined core + SSG program appeared to provide additional benefits in certain anaerobic and aerobic performance parameters, particularly VO₂max, V_IFT, and RAST power variables. Improvements in sprint,

agility, and countermovement jump performance were generally observed in both groups, although several Time $\times$ Group interaction effects were not statistically significant. Therefore, these findings should be interpreted with caution due to methodological limitations, particularly the unequal overall training stimulus and the lack of objectively matched training loads between groups. From a practical perspective, integrating core exercises with soccer-specific small-sided games may provide an efficient and sport-specific training approach for developing multiple physical performance components simultaneously in youth soccer players. Future studies should further investigate the independent and combined effects of these training models using larger sample sizes and more controlled training load monitoring procedures.

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