

Adaptations in neuromuscular performance following a 12-week combined in-season training program in youth soccer players

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Abstract

Purpose: This study examined the effects of a 12-week in-season combined training program on neuromuscular performance in youth soccer players. **Methods:** Forty-eight U15 male soccer players (14–15 years) participated via a pre–post repeated-measures design. Participants were divided into 3 groups, a Combined Fitness Training Group (CFTG; n = 16), a Soccer Training Group (STG; n = 16), and a Control Group (CG; n = 16). The intervention lasted 12 weeks during the competitive season and consisted of 4-weekly training sessions and one match. The CFTG followed a combined training program in addition to soccer training with functional strength training, sprint development, change-of-direction (COD) drills, and intermittent aerobic training, while the STG followed a program with physical condition being trained only with soccer training. Squat jump (SJ), countermovement jump (CMJ), CMJ with arm swing (CMJ-AS), 10–20–30 m sprint tests, Illinois agility (right and left), were used for the assessment of neuromuscular performance. A repeated measures ANOVA was performed for statistical analysis. **Results:** Significant interactions were observed for sprint (10–20–30 m; p<0.001), vertical jump (SJ, CMJ, & CMJ-AS; p<0.01), and Illinois tests (p<0.05). The CFTG demonstrated the greatest improvements, with the largest adaptation observed in CMJ-AS (+19.21%) and 30-m sprint (-3.19%). No changes were detected in CG. **Conclusion:** A specialized in-season combined training program significantly enhances sprint acceleration, explosive power, and agility in young soccer players compared with soccer-only training. These findings support the integration of targeted neuromuscular conditioning within competitive-season microcycles in youth soccer academies.

Keywords: neuromuscular performance, sprint acceleration, plyometric training, change-of-direction, youth soccer, combined training

Introduction

Soccer performance is characterized by high-intensity interval movements and prolonged submaximal activity. During a match, players perform repetitive accelerations, decelerations, sprints, changes of direction (COD), jumps, and technical actions that are alternated with periods of active recovery. Although most of the actions are often anaerobic, aerobic metabolism dominates during a 90-minute match, with players often operating at ~70–80% of maximal oxygen uptake (VO₂max) (Stolen T, 2005, et al, Bangsbo J, 2006, et al). The aerobic system also supports repeated high-intensity performance through phosphocreatine synthesis, metabolite clearance, and maintenance of work rate (Mohr M, et al, 2003, 2008). Recent load monitoring and competition analysis research further highlights that appropriate training load distribution during the season and adequate execution of high-intensity movements are important for maintaining performance potential during the competitive season (Poulios A, 2025).

Neuromuscular properties - particularly explosive strength, sprint acceleration (10-30 m) and COD capacity - are important determinants of football performance beyond the aerobic mechanism (Poulios A, 2025, Tzatzakis T, 2019). In competitive soccer, rapid acceleration and deceleration ability give players an advantage during high-pressure actions, such as continuous transitions and 1v1, while vertical jumping ability is important for repetitive high-intensity actions (Ispiridis I, 2024). In youth football, maximizing neuromuscular development is also critical because adolescence is characterized as a sensitive period for athletic development, with maturation influencing strength and power training capacity, motor skills and injury risk profiles (Lloyd R 2012, Malina R, 2015). High-performance young players can achieve significant improvements in strength and

speed through specific strength interventions, plyometrics, and combination training programs that incorporate acceleration, deceleration, sprinting, and jumping elements (Oliver JL, 2024).

Field tests such as the squat jump (SJ), the countermovement jump (CMJ), and CMJ variations (e.g., CMJ-AS) are widely used to quantify explosive lower extremity strength and stretch-shortening cycle (SSC) function and are frequently applied to assess training adaptations (Poullos A, 2025, 2018). In addition, 10-30 m sprint tests provide valid indicators of acceleration and speed development, while agility/COD tests (e.g., Illinois) quantify the ability to effectively decelerate and reaccelerate - key elements of the movement demands specific to soccer (Poullos A, 2025, Tzatzakis T, 2019). Training programs for neuromuscular development in soccer include strength training, plyometrics, sprint training, and combination models (Poullos A, 2025, Draganidis D, 2015).

A recent review suggests that plyometric training provides significant benefits for adolescent soccer players in jumping, sprinting, and COD abilities compared to technical – tactical soccer training, supporting its inclusion as a targeted stimulus during the development of young soccer players (Zhang F, 2026). In addition, combined programs that include strength, plyometrics, and sprinting stimuli have shown positive effects on repeated sprinting ability and overall performance in team sports athletes (Liu H, 2024). More generally, combined plyometrics-sprinting programs are increasingly emerging as effective methods for maximizing sprint performance and movement efficiency in youth soccer athletes (Aloui G, 2021).

However, the application of neuromuscular development during in-season presents practical limitations. The in-season microcycle is usually used more in tactical preparation for the match and recovery to avoid excessive fatigue (Poullos A, 2025). Short-term games (SSGs) are commonly used because they include technical-tactical goals with fitness stimuli (Ispirlidis I, 2024). However, SSG-based training can improve multiple fitness outcomes, while running-based HIIT can provide greater adaptations to sprint performance, while both methods can yield similar results in vertical jumps and COD - suggesting that SSGs alone may not maximize all neuromuscular factors (Ispirlidis I, 2024, Clemente FM, 2019). An additional programming parameter is the alternation of training elements (e.g., strength and high-endurance). Recent evidence in young soccer players suggests that the order and structure of concurrent training within the same session can influence fitness adaptations, highlighting the importance of thoughtful microcycle design (Blechschmied R, 2024). Evidence supports that in-season neuromuscular improvements are achievable when the training design includes specific stimuli (strength/plyometrics/sprinting/COD), with appropriate intensity distribution and recovery management (Tzatzakis T, 2019, Poullos A, 2018).

Therefore, the aim of the present study was to examine the effect of a 12-week combined fitness training program in addition to in-season soccer training on neuromuscular performance in adolescent soccer players, specifically assessing vertical jump performance (SJ, CMJ, CMJ-AS), 10–20–30 m sprint time, and agility/COD performance test.

Material & Methods

Participants

Forty-eight young male soccer players (age 14–15 years) from a competitive soccer academy participated in the study, and divided into three groups: Combined Fitness Training Group (CFTG; n = 16), Soccer Training Group (STG; n = 16), Control Group (CG; n = 16). Following an analytical explanation of the study's goals, and procedures, the participants signed a written consent form and answered a series of medical questions. All participants were active football players in youth academy teams (U15) that competed in the local development league and were free from injury and actively competing during the intervention period. (Table 1)

Table 1. Participants' Characteristics at Baseline

Variable	CFTG (n = 16)	STG (n = 16)	CG (n = 16)
Age (years)	14.8 ± 0.4	14.7 ± 0.5	14.8 ± 0.3
Height (cm)	168.4 ± 6.2	169.1 ± 5.8	167.9 ± 6.5
Body Mass (kg)	59.3 ± 5.4	60.1 ± 6.0	58.7 ± 5.8
Training Experience (years)	4.1 ± 1.2	4.3 ± 1.0	4.0 ± 1.3

CFTG, combined fitness training group; STG, soccer training group; CG, control group; n, number.

Study Design

Before the intervention begins the height of participants was estimated as previously described (19). Also, the body mass of participants was measured as previously described (19). A 12-week intervention program of four mesocycles of three weeks each, during in-season using a pre–post repeated-measures design. Assessments were conducted one week prior to the intervention (Pre) and immediately after completion of the 12-week program (Post). A Group × Time repeated-measures analysis was applied to determine differential adaptations between groups.

Training Intervention

The intervention lasted 12 weeks (**Table 2**) and consisted of four mesocycles of three weeks each. Each week included four training sessions and one official match. The Combined Fitness Training Group (CFTG) followed a combined training model that included functional strength training (core and lower-limb strength circuits), speed and sprint development, change-of-direction and agility drills, intermittent aerobic training (4×4 min at 80% vVO_{2max}), Small-Sided games (1v1–6v6 formats), and large-sided tactical games (7v7–11v11), with the program incorporating planned progressive overload across mesocycles, while the Soccer Training Group (STG) followed the standard soccer training program of the academy, which included technical–tactical drills, small-sided games (1v1–6v6 formats), large-sided tactical games (7v7–11v11), and match preparation sessions, with no strength, sprint, or specific aerobic conditioning protocols implemented outside of soccer-specific drills.

Table 2. Weekly Microcycle Comparison

Day	CFTG	STG
Monday	25' Functional strength + core 55' Technical Session	80' Technical–Tactical session
Tuesday	35' Speed & sprint development 40' Technical – Tactical -Drills	75' Technical – Tactical drills
Wednesday	25' Intermittent aerobic training (4×4 min at 80% vVO_{2max}) 60' Tactical Session	85' Technical - Tactical session
Thursday	Small-sided games – Tactical Session	Small-sided games – Tactical Session
Saturday	Official match	Official match

CFTG, combined fitness training program; STR, soccer training program; vVO_{2max} , velocity at maximal oxygen uptake.

Neuromuscular Performance Assessment

The following tests were performed pre- and post-intervention: SJ, CMJ, CMJ-AS was performed as previously described (6, 20). The sprint of 10 m, 20 m and 30 m, was executed as previously described (12). The Illinois Agility Test (Right & Left side) was examined as previously described (21). All tests took place on the same surface under standardized environmental conditions.

Statistical Analysis

Data were analyzed using SPSS (version 25). One-way ANOVA was used to verify baseline homogeneity. Repeated-measures ANOVA (Group $\times$ Time) was applied to determine interaction effects and paired t-tests were used for within-group comparisons. Statistical significance was set at $p \leq 0.05$.

Results

Sprint and agility Performance

In 10 m sprint, both intervention groups showed significant improvements. In the CFTG group, performance improved from 1.794s (SD = 0.089) to 1.764s (SD = 0.072) ($t = 1.795$, $p = 0.023$), corresponding to a -1.672% change. Similarly, the STG group improved from 1.893s (SD = 0.097) to 1.873s (SD = 0.093) ($t = 5.477$, $p = 0.000$), with a -1.057% change. Statistical differences between CFTG and STG also showed after the intervention program with better improvements for the CFTG group ($p = 0.001$). In contrast, the CG group showed a small, non-significant improvement from 1.934s (SD = 0.109) to 1.923s (SD = 0.098) ($t = 0.787$, $p = 0.444$), corresponding to a -0.582% change.

In 20 m sprint, significant improvements were again observed in both intervention groups. The CFTG group improved from 3.196s (SD = 0.160) to 3.154s (SD = 0.148) ($t = 3.083$, $p = 0.008$), with a -1.291% change. The STG group improved from 3.310s (SD = 0.175) to 3.293s (SD = 0.170) ($t = 7.519$, $p = 0.000$), corresponding to a -0.529% change. Statistical differences between CFTG and STG also showed after the intervention program with better improvements for the CFTG group ($p = 0.000$). The CG group showed a minimal and non-significant change from 3.386s (SD = 0.192) to 3.376s (SD = 0.178) ($t = 0.103$, $p = 0.919$), with a -0.314% change.

In 30 m sprint, both intervention groups continued to demonstrate significant improvements. The CFTG group improved from 4.576s (SD = 0.254) to 4.501s (SD = 0.257) ($t = 3.136$, $p = 0.007$), showing a -1.639% change. The STG group improved from 4.686s (SD = 0.253) to 4.651s (SD = 0.246) ($t = 6.682$, $p = 0.000$), with a -0.734% change. Statistical differences between CFTG and STG also showed after the intervention program with better improvements for the CFTG group ($p = 0.000$). In contrast, the CG group showed a small and non-significant improvement from 4.812s (SD = 0.272) to 4.801s (SD = 0.253) ($t = -1.947$, $p = 0.071$), corresponding to a -0.234% change.

In agility Test (Illinois agility test), only the CFTG group demonstrated a statistically significant improvement. Specifically, performance in the CFTG group improved from 17.373s (SD = 0.760) to 17.036s (SD = 1.104) ($t = 1.946$, $p = 0.041$), corresponding to a -1.936% change. In contrast, the STG group showed a minimal and non-significant change from 17.269s (SD = 1.000) to 17.243s (SD = 1.081) ($t = 0.422$, $p = 0.679$), with a -0.152% change. Statistical differences between CFTG and STG also showed after the intervention program with better improvements for the CFTG group ($p = 0.044$). Similarly, the CG group demonstrated a small, non-significant improvement from 17.386s (SD = 0.851) to 17.284s (SD = 1.082) ($t = 0.788$, $p = 0.443$), corresponding to a -0.582% change. (**Figure 1**)

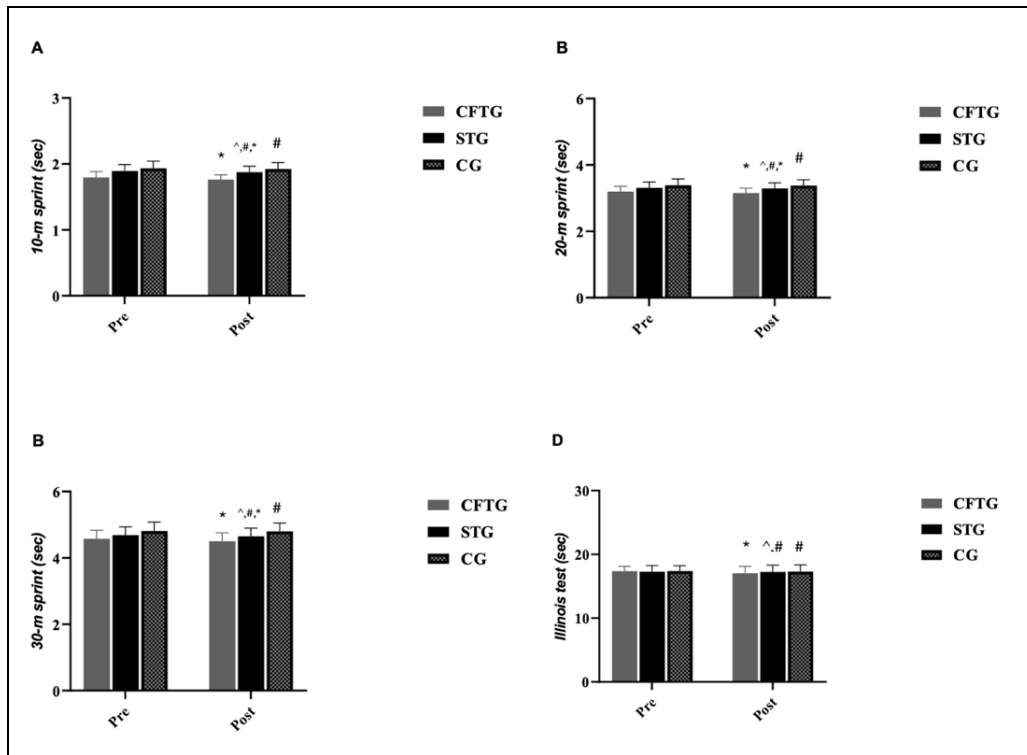


Figure 1. Changes in 10-m sprint time (A), 20-m sprint time (B), 30-m sprint time (C) and, Illinois test (D). Means and standard deviations are presented via vertical bars (N = 46). * Differences between pre and post timepoints, # Differences among CG and CFTG and STG, ^Differences between CFTG and STG.

Jump Performance

In Squat Jump (SJ), only the CFTG group demonstrated a statistically significant improvement. Specifically, performance increased from 25.87cm (SD = 5.34) to 28.34cm (SD = 3.20) ($t = -2.711$, $p = 0.016$), corresponding to a 9.544% improvement. The STG group showed a small, non-significant increase from 23.46cm (SD = 6.31) to 24.01cm (SD = 5.94) ($t = -1.801$, $p = 0.092$), with a 2.318% change. Statistical differences between CFTG and STG also showed after the intervention program with better improvements for the CFTG group ($p = 0.009$). In contrast, the CG group showed a slight, non-significant decrease from 23.63cm (SD = 6.36) to 23.37cm (SD = 6.32) ($t = 0.595$, $p = 0.561$), corresponding to a -1.132% change.

In Counter Movement Jump (CMJ), both intervention groups showed improvements, but only the CFTG and STG groups reached statistical significance. The CFTG group improved from 25.98cm (SD = 5.37) to 29.35cm (SD = 4.45) ($t = -3.777$, $p = 0.002$), with a 12.948% increase. Similarly, the STG group improved from 26.23cm (SD = 4.90) to 27.35cm (SD = 4.87) ($t = -7.215$, $p = 0.000$), corresponding to a 4.267% increase. Statistical differences between CFTG and STG also showed after the intervention program with better improvements for the CFTG group ($p = 0.000$). The CG group showed a small, non-significant improvement from 26.15cm (SD = 4.91) to 26.60cm (SD = 4.99) ($t = -1.347$, $p = 0.198$), with a 1.719% change.

In Counter Movement Jump with arm swing (CMJ-AS), both intervention groups demonstrated statistically significant improvements. The CFTG group showed a substantial increase from 30.29cm (SD = 7.56) to 36.10 cm (SD = 4.78) ($t = -5.138$, $p = 0.000$), corresponding to a 19.207% improvement. The STG group also improved from 31.47cm (SD = 7.40) to 32.62 cm (SD = 7.39) ($t = -7.476$, $p = 0.000$), with a 3.628% increase. Statistical differences between CFTG and STG also showed after the intervention program with better

improvements for the CFTG group ($p = 0,000$). In contrast, the CG group showed a small, non-significant improvement from 31.69cm (SD = 7.29) to 32.15 cm (SD = 7.55) ($t = -1.230$, $p = 0.238$), corresponding to a 1.465% change. (**Figure 2**)

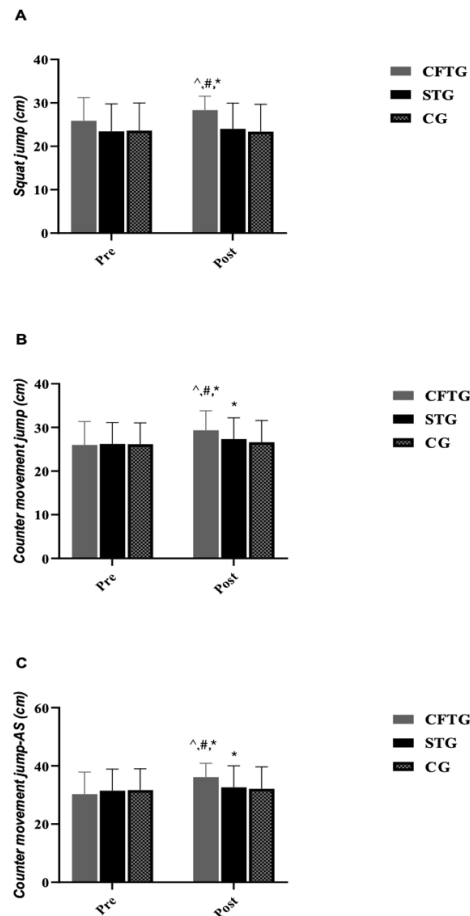


Figure 2. Changes in Squat Jump Height (A), Counter Movement Jump (B) and Counter Movement Jump - AS (C). Means and standard deviations are presented via vertical bars (N = 46). * Differences between pre and post timepoints, # Differences among CG and CFTG and STG, ^Differences between CFTG and STG.

Discussion

The present study investigated the effects of a 12-week in-season combined training program on neuromuscular performance in young soccer players. The main findings indicate that the CFTG achieved significantly greater improvements in sprint performance (10–30 m), vertical jump performance (SJ, CMJ, CMJ-AS), and agility (Illinois tests) compared with the STG and CG. These results confirm that combined training program provide neuromuscular adaptations during the competitive season, beyond those achieved through standard soccer training alone (11). The improvements observed in 20 m and 30 m sprint performance suggest enhanced acceleration mechanics and improved speed maintenance capacity. Sprint performance in youth soccer is strongly associated with horizontal force production and rate of force development (22, 23). The improvement observed in the CFTG agrees with previous in-season studies, showing that targeted sprint and strength integration produces moderate-to-large gains in acceleration and maximal speed (15, 23). Meta-analytic evidence further supports that strength–speed combined programs are superior to soccer-only training for sprint enhancement in youth athletes (24). Significant improvements in SJ, CMJ, and CMJ-AS indicate enhanced lower-limb explosive power and stretch–shortening cycle (SSC) efficiency. Vertical jump performance is closely linked to sprint acceleration and change-of-direction ability in soccer players (25). Improvement in CMJ-AS (+19.21%) suggests enhanced neuromuscular coordination and elastic energy utilization. Combined strength and plyometric stimuli are known to improve SSC function by increasing motor unit recruitment, tendon stiffness, and rate of force development (26).

Agility and change-of-direction (COD) performance improved significantly only in the CFTG, suggesting that soccer-specific exposure alone may not provide sufficient overload to enhance braking and re-acceleration capacity. COD performance depends heavily on eccentric strength, reactive strength, and neuromuscular control during deceleration (6). Previous studies indicate that structured neuromuscular and strength training programs are more effective than technical drills alone in improving COD performance (27). Furthermore, recent research suggests that combined sprint–strength–plyometric training enhances deceleration efficiency and directional speed more effectively than Small-Sided games only (28).

Soccer training contains intermittent and multidirectional movements; however, it may lack sufficient intensity and overload to drive neuromuscular adaptation when performed without supplemental conditioning (1, 29). This limitation becomes more pronounced during the in-season, where training volume is constrained. The present findings reinforce the growing evidence that integrated combined training models can maintain or enhance explosive performance capacities during competitive periods (9). In contrast, Small-Sided games may improve aerobic capacity but produce limited improvements in maximal sprint and power variables (28). The neuromuscular improvements observed are likely mediated by increased motor unit recruitment, improved intermuscular coordination, and enhanced rate of force development (26). Sprint and jump training may have optimized horizontal force production and SSC utilization, while structured strength work likely enhanced tendon stiffness and neuromuscular synchronization (30). Adolescence represents a favorable window for neuromuscular development due to neural plasticity and trainability of explosive strength (31).

Practical Applications

For youth academies, in-season neuromuscular development is feasible when structured strength and sprint elements are integrated into training, as soccer-only training may not be sufficient to optimize explosive performance; consequently, combined training models appear particularly effective for improving sprint acceleration and vertical jump performance, findings that align with Long-Term Athlete Development principles emphasizing progressive and integrated physical development (9).

Conclusion

The present study demonstrated that a combined 12-week in-season training program significantly enhanced neuromuscular performance in youth soccer players compared with standard soccer training and control conditions. The Combined Fitness Training Group (CFTG) exhibited superior improvements in sprint acceleration (10–30 m), vertical jump performance (SJ, CMJ, CMJ-AS), and agility (Illinois tests), with moderate to very large interaction effect sizes observed across key variables. The most pronounced adaptations were detected in CMJ-AS and 30 m sprint performance, indicating substantial improvements in stretch–shortening cycle efficiency, coordinated explosive power, and speed maintenance capacity. In contrast, soccer-only training resulted in smaller performance gains, while the control group demonstrated minimal or no meaningful changes. These findings suggest that neuromuscular qualities can be effectively developed during the competitive season when conditioning elements—such as structured strength, sprint, and change-of-direction training—are systematically integrated within the weekly microcycle. Importantly, the implementation of a combined training model did not hinder competitive participation, supporting its practical feasibility in youth academy environments.

Declaration of generative AI and AI-assisted technologies in the writing process, During the preparation of this work, Corresponding Author, Stergios N. Komsis used ChatGPT (OpenAI) to enhance the quality of figures and to assist with the refinement of formal English translations where appropriate. Following the use of this tool, all generated content was carefully reviewed and edited by the author, who assumes full responsibility for the accuracy and integrity of the final publication.

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