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Section III – Sports and Physical Activity

Effects of Run-Specific Isometric Exercises Performed with Complex Training on Neuromuscular Performance in Youth Soccer Players

by

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The present study explored whether incorporating run-specific isometric exercises (RSIso) into a complex training (CT) routine would provide additional benefits for youth soccer players during the in-season. Twenty-four male athletes (aged 18–19 years) were randomly divided into two groups: one following a conventional CT program and the other performing an identical program preceded by isometric conditioning training (IST-CT). Both interventions were carried out twice per week for eight weeks, with equivalent training volume and intensity. Performance outcomes were assessed through countermovement jump, drop jump, broad jump (BJ), 30-m linear sprint, and the 5-0-5 change-of-direction (COD) tests. Two-way mixed-design ANOVA (between-subjects factor: group [IST-CT vs. CT]; within-subject factor: time [pre vs. post]) revealed significant main effects of time for COD ability with the non-dominant leg ($p = 0.01$). Significant group × time interactions were observed for peak power ($p = 0.01$) and BJ performance ($p = 0.03$), yet post-hoc comparisons did not confirm statistically meaningful differences (all $p > 0.05$). Overall, both training approaches led to comparable adaptations in strength-speed performance. Although the direction of changes tended to favor the IST-CT condition, the modest magnitude of effects does not allow to draw definitive conclusions regarding its superiority over conventional CT, indicating that further research is required to confirm the practical relevance of these findings.

Keywords: *athletes; running; motor skills; isometric contraction*

Introduction

Complex-contrast training (CT) is recognized as a training method that integrates high-load resistance exercises with low-intensity ballistic movements and involves the use of two biomechanically similar exercises performed with different loads and movement velocities, applied in a set-by-set manner (Cormier et al., 2022; Thapa et al., 2024), for instance, heavy-load squats performed prior to vertical jumps (Biel et al., 2023). The integration of exercises from both ends of the force-velocity spectrum facilitates improvements in motor performance (e.g., sprinting and jumping) by enhancing the ability to produce high levels of force while maintaining elevated movement velocities (Li et al., 2026; Loturco et al., 2022; Thapa, 2022). This is of particular importance in high-intensity sports, including soccer (Filter et al., 2023).

Despite numerous studies demonstrating the effectiveness of CT in enhancing motor abilities of soccer players (Krzysztofik et al., 2025; Thapa et al., 2021, 2022), further optimization of CT protocols remains warranted. This need pertains particularly to strategies that do not replace the classical CT structure, but rather provide an additional stimulus that may enhance adaptive potential and training specificity. One such a modality includes isometric strength training (IST), which has been shown to induce neuromuscular adaptations at a relatively low fatigue cost (Lum and Barbosa, 2019). Existing reviews indicate that IST can increase maximal

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force production, the rate of force development (RFD), and performance in dynamic tasks (e.g., jumping and sprinting), despite the absence of joint movement (Lum and Barbosa, 2019; Korkmaz et al., 2026). Integrating IST targeted at key joint angles may therefore better prepare the neuromuscular system for CT efforts; however, empirical evidence confirming the superiority of this approach over CT alone is currently lacking. Among the potentially promising forms of IST, there is growing interest in the so-called running-specific isometrics (RSIso), which represents an extension of classical IST and is intended to improve the transfer of adaptations to speed-strength tasks. Despite its use in applied sport settings, RSIso has not yet been systematically described or empirically validated. RSIso exercises, classified as pushing isometric muscle actions (PIMA) according to the typology proposed by Schaefer et al. (2017), are performed unilaterally in positions that biomechanically resemble the mid-stance phase of high-speed running. The purpose of this configuration is to isolate key muscle groups surrounding the ankle, knee, and hip joints, which may be particularly relevant for the physical preparation of soccer players (Buchheit, 2019). Preliminary reports suggest that RSIso may enhance sprint performance as well as outcomes in explosive lower-limb tasks such as the countermovement jump (CMJ) and the standing broad jump (BJ) (Bellinger et al., 2021; Hamad et al., 2026). Both the CMJ and the BJ require rapid force generation through a coordinated extension of the hip, knee, and ankle joints, making them important indicators of general athletic performance (Mackala et al., 2013; Mero et al., 1992). Consequently, increasing isometric strength in positions that are functionally related to sport-specific efforts may form the basis for improved transfer of training adaptations. However, no studies have yet confirmed that long-term integration of RSIso-targeted IST with CT (IST-CT) yields greater benefits than CT alone.

Considering the previously mentioned gaps in the literature regarding the integration of CT and IST-CT, the aim of this study was to compare the effects of an 8-week CT protocol preceded by IST exercises with a conventional CT protocol in soccer players during the in-season. We focused on changes in linear sprint performance (SP), change of direction (COD), drop jump (DJ), BJ and CMJ performance. It was hypothesized that incorporating an IST block including RSIso exercises immediately prior to CT would lead to greater improvements in sprinting and jumping performance than a traditional CT protocol without IST integration.

Methods

A randomized, single-blind, parallel intervention study was conducted to compare the effects of CT with an additional block of IST and traditional CT on jumping performance, SP, and COD. Participants were randomly allocated to an 8-week training protocol involving either IST-CT or CT, performed twice per week during the in-season period. The included soccer players completed experimental sessions on days 3 and 5 post-match. The order of conditions was counterbalanced and randomly assigned to each participant using an online randomization tool (randomization.org). Pre- and post-training assessments were conducted one week before the first session and after the last session. Physical performance was evaluated using CMJ, DJ, BJ, SP, and COD tests. All participants were familiar with the tests, as they were part of the standard testing battery applied during the preseason period. Familiarization with IST and maximum voluntary isometric contraction was provided during a dedicated introductory session conducted one week prior to the main testing period.

Participants

The experiment involved 24 soccer players, classified as highly trained (Tier 3) according to McKay et al. (2022), selected from youth players from two different clubs participating in the Polish first league (age range: 18–19 years; body mass: 70 ± 8 kg; body fat content: 7 ± 2.6%; body height: 178 ± 7 cm; soccer training experience: 5 ± 1 years; resistance training experience: 3 ± 1 years) (Figure 1). Participants were included in the study based on the following criteria: i) absence of neuromuscular and musculoskeletal disorders, ii) at least two years of experience in resistance training, iii) regular participation in both soccer and resistance training for at least one year prior to the study commencement.

Participants were instructed to refrain from performing additional resistance exercises during the study course and within 48 h before the baseline examination to prevent fatigue. Additionally, they were advised to maintain their regular eating and sleeping habits, avoid alcohol consumption, and refrain from using any supplements or stimulatory substances, except for usual supplements such as creatine. At the beginning of the experimental session, body composition was assessed using multi-frequency bioelectrical impedance analysis under controlled laboratory conditions with the InBody 770 device (InBody 770 Biospace Co., Ltd, Seoul, South Korea). All participants were informed about the potential risks and benefits of the study, as well as their right to withdraw from the study at any time without providing a reason. Written informed consent for participation in the study was obtained from all participants, albeit without disclosing specific details regarding the study's objectives and anticipated outcomes. The study protocol was approved by the Bioethics Committee for Scientific Research at the Jerzy Kukuczka Academy of Physical Education in Katowice, Katowice, Poland (approval code: 03/2021; approval date: 27 May 2021) and complied with the ethical standards outlined in the 2013 Helsinki Declaration.

A sample size estimation using G*Power software (version 3.1.9.2, Dusseldorf, Germany) showed that to provide 80% power with a significance level of 0.05, correlation among repeated measures of 0.5 in this study design (n = 24; two-way repeated-measures ANOVA, within-between interaction), an effect size of approximately f = 0.3 would be required. This value of effect size was chosen according to findings from Krzysztofik et al. (2025) and Thapa et al. (2021) on the impact of CT on SP, jump and COD ability of soccer players. All participants represented a homogeneous group of youth soccer players of comparable age, training experience, and performance level, despite originating from two different clubs. No significant baseline differences were observed among the players across the assessed performance variables (all p > 0.05).

Training Programs

The 8-week IST-CT and CT programs are outlined in Tables 1 and 2. The training programs differed in that, in the IST-CT program, participants performed an additional block of isometric PIMA exercises at the beginning of each session, reflecting current practice trends related to RSIso that have not yet been formalized in the scientific literature. All training sessions were supervised by the same strength and conditioning coaches, and each session began (at the same time of the day, between 15:00 and 17:00) with a standard general soccer warm-up. The program was divided into two phases: weeks 1–4 and 5–8, in which different exercises were applied with progressively increasing intensity and training volume.

Procedure of Isometric Training

Ankle and Knee Iso-Push

The individual rack height for the execution of both isometric exercises was determined during the familiarization session based on the placement of the safety pins securing the barbell. Participants held the barbell resting on their shoulders, with its position stabilized by the pins, enabling isometric muscle contraction. During the knee iso-push exercise, the lower limb was positioned such that the midfoot was aligned directly beneath the barbell's axis. The knee joint angle ranged approximately from 135 to 145°, while the hip joint angle was set at approximately 160–170°. In the ankle iso-push exercise, the pad of the toe of the tested limb was aligned directly beneath the barbell’s axis, resulting in a slight forward lean of the torso. The exercise was structured into two phases: in the first phase, the knee was flexed, and in the second phase, the knee was extended. During both phases, the ankle joint was maintained in a neutral position or in plantarflexion of up to approximately 10°. The progression from bent to straight knee was applied to ensure sequential activation of both major plantarflexor muscle groups: the bent-knee position preferentially engages the soleus, whereas the straight-knee position increases the contribution of the gastrocnemius (Sasaki et al., 2012). This design allowed for a more comprehensive strengthening of the ankle plantarflexors across different functional conditions. All joint angle measurements were conducted by an experienced coach using a goniometer (EasyAngle, Meloq AB, Stockholm, Sweden). A certified weightlifting coach standardized body positioning to ensure a vertical trunk posture in both exercises. Upon the investigator's command, participants were instructed to "push the barbell vertically upward as hard and as fast as possible" (Jarosz et al., 2025a) while pressing their back against the barbell and exerting force through the foot into the ground in accordance with the number of repetitions, position and duration specified in the training periodization plan (Tables 1 and 2). To ensure a consistent level of effort during each isometric contraction trial, participants were provided with strong verbal encouragement throughout the test, in accordance with commonly applied procedures in neuromuscular research (McNair, 1996).

Hip Iso-Push

The procedure was conducted in a manner similar to the previously described exercises. The athlete was positioned supine on the floor, with the lower portion of the scapulae resting on a 15-cm elevation to ensure comfort and stability. The heel of the tested limb was placed on a 10 cm platform, while a fixed bar was positioned at the level of the hip crease to serve as a contact point. The joint angles for the knee and the hip were standardized at approximately 135–145° and 160–170°, respectively, in alignment with the previously adopted values used in the knee iso-push test.

Countermovement and Drop Jump Assessment

The CMJ and DJ performance was evaluated using a valid and reliable force plate (ForceDecks, Vald Performance, Australia) sampled at 1000 Hz (Collings et al., 2024; Schoenfeld et al., 2015). Vertical jump height was calculated using the impulse-momentum method, based on the relationship between the net force impulse and take-off velocity (Hojka et al., 2022). The net impulse was obtained by integrating the vertical ground reaction force signal minus body weight from the start of the movement to toe-off. The take-off velocity (TOV) was then computed using the impulse-momentum equation (impulse = m · Δv), and jump height was calculated from take-off velocity using the standard projectile equation:

$$\text{Jump height} = \frac{1}{2} \cdot \left(\frac{\text{TOV}^2}{g} \right)$$

where:
TOV: vertical velocity of the center of mass at the take-off;
$g = 9.81 \cdot s^{-2}$.

For the CMJ test, participants started from a standing position, with hands on their hips, maintaining an upright posture to minimize angular displacement of the hips. They were instructed to remain still for at least one second before initiating the downward phase of the jump. They were then instructed to move downward to a self-selected depth, followed by a dynamic upward motion to reach the maximum jump height, repeating the procedure three times to complete three jumps in total. It was required that participants landed in the same position from which they started, centrally on the force plate. The primary dependent variable in the study was jump height (JH), which was calculated based on the center of mass velocity at the take-off, using an equation related to the impulse and momentum. Additionally, relative peak power (PP) was obtained for each trial. The best result considering the jump height was registered for further analysis.

For the DJ test, participants began in an upright position with their hands placed on their hips and were instructed to "step off the box with one foot and jump as quickly and as high as possible after ground contact". This verbal cue was used to ensure that the task conformed to the accepted definition of a drop jump aimed at assessing reactive strength. A standardized 45-cm box height was used. Participants were instructed not to actively jump upward from the box, but to initiate the drop passively and to minimize ground contact time. Each trial was performed with both the contact and landing phases executed entirely on the force plate. The jump was deemed invalid if the participant lifted their legs during flight, landed partially or fully outside the force plate area, or stepped off the box instead of performing a controlled drop. The procedure continued until three valid trials were collected, with the best performance defined as the attempt with the highest reactive strength index (RSI) used for further analysis. The reactive strength index modified (RSI-mod) was calculated using the impulse-momentum method as the take-off velocity (TOV) divided by the time from initial ground contact to take-off, with ground contact time obtained directly from the force plate data. This provided a measure of explosive strength expressed in m/s.

Broad Jump Testing

The BJ was performed as a bilateral standing long jump, with the allowance for a take-off movement. High test reliability had been documented in prior research, with Rahman et al. (2021) reporting an intraclass correlation coefficient of 0.97 for the same measurement protocol. Instructions for participants included knee flexion (with the option to choose the depth of the bend at their discretion) and positioning of the arms behind the torso. They were then instructed to generate a strong impulse by extending their legs, throwing their arms forward, and executing a maximal jump for the furthest possible distance. The jump distance was measured from the starting line to the nearest heel in cm. Each participant performed three attempts, with a 30-s rest interval in between. The best result was registered for further analysis (Krzysztofik et al., 2025).

Linear Sprint Time and 5-0-5 Change of Direction Assessment

In the linear sprint test, participants ran a distance of 30 m. The running time was recorded using photocells (Swift Performance, Wacol, Queensland, Australia), which demonstrated high precision and reliability during the measurement of the 10-m sprint (intraclass correlation coefficient = 0.93) (Stanton et al., 2016). Gates were set at 0 m and 30 m based on previous CT studies (Dello Iacono and Seitz et al., 2018). The height of the photocells was approximately 1 m above the ground, corresponding to the participants' hip height, in order to prevent accidental triggering of the photocells by leg or arm movements. Participants started with their front foot positioned 0.3 m behind the first photocell to prevent premature activation of the device. Three attempts were completed, with the best time (for 30 m) included in subsequent analysis.

For the 5-0-5 change of direction (COD) test, participants ran as quickly as possible in a straight line from the starting point to 5 m, touching the line on the ground with their foot, and then returned to the starting point after a 180° turn. The gates were set at 0 m and 5 m, and their configuration was similar to that in the linear sprint test (Krzysztofik et al., 2025). The test involved two trials with a turn on each leg, performed in random order (a total of four trials), with the best time used for further analysis.

Statistical Analysis

Within-session reliability was assessed using intraclass correlation coefficients (ICCs) calculated from repeated trials performed within the same testing session. ICCs were computed using a two-way random-effects model with consistency. Ninety-five percent confidence intervals (95% CI) were provided. ICC values were interpreted according to the guidelines proposed by Koo and Li (2016), with values <0.50 indicating poor, 0.50–0.75 moderate, 0.75–0.90 good, and >0.90 excellent reliability. Reliability classification was based on the lower bound of the 95% CI. Variables demonstrating insufficient reliability, defined as a lower bound of the 95% CI below 0.50, were not considered for further inferential interpretation. All reliability analyses were performed in Jamovi v.2.6.25 (The Jamovi project, 2025, Sydney, Australia).

Descriptive statistics were reported as means and standard deviations (± *SD*), along with 95% confidence intervals (95% CI). The Shapiro-Wilk test was used to assess the normality of data distribution, while the Levene's test was applied to verify the homogeneity of variances. A 2 × 2 mixed-design ANOVA with condition (CT vs. IST-CT) as a between-subjects factor and time (pre vs. post) as a within-subject factor was performed to examine the effects of the interventions on physical performance outcomes. Effect sizes for ANOVA were reported using partial eta squared (η^2_p), interpreted as small (≥ 0.01), medium (≥ 0.06), and large (≥ 0.14). In cases where a significant interaction was identified, Bonferroni-adjusted post hoc tests were used for pairwise comparisons. To characterize the magnitude of mean differences, standardized effect sizes (Hedges' *g*) were computed and interpreted following commonly accepted thresholds (*g* < 0.2: trivial, 0.2–0.6: small, 0.6–1.2: moderate, >1.2: large).

Following the main analysis, participants were categorized based on their individual responses to the intervention using the smallest worthwhile change (SWC). In accordance with the recommendations by Turner et al. (2015), the SWC was calculated by multiplying the between-subject standard deviation at baseline by 0.6 (SWC = 0.6 × SD_{baseline}). Participants were considered responders when the observed change exceeded the SWC threshold. To verify the appropriateness of the SWC threshold, the typical error (TE) was calculated as: TE = *SD* pre-post difference/√2 and then, the signal-to-noise ratio (SNR) was calculated as: SNR = SWC/TE. An SNR value greater than 1.0 was considered indicative of a reliable SWC estimate. A chi-square (χ^2) test was used to evaluate whether the frequency of responders and non-responders differed significantly between the intervention conditions. Given the relatively small sample size and low expected frequencies in some contingency table cells, both the chi-square (χ^2) test and the Fisher's exact test were used to compare the distribution of responders and non-responders between groups. In addition, effect sizes for the chi-square tests were expressed as Cramér's *V*, and interpreted as weak (>0.05), moderate (>0.10), strong (>0.15), or very strong (>0.25), in accordance with Akoglu (2018). Statistical significance was set at $p < 0.05$. All analyses were performed using Statistica software (version 13.3; StatSoft, Kraków, Poland).

Results

Within-session reliability analysis demonstrated good reliability for CMJ height (ICC = 0.91, 95% CI = 0.80–0.96). Good reliability was observed for peak power (ICC = 0.88, 95% CI = 0.76–0.96) and the modified RSI (ICC = 0.89, 95% CI = 0.77–0.96). BJ performance demonstrated good reliability (ICC = 0.89, 95% CI = 0.82–0.98), while linear sprint speed showed moderate reliability (ICC = 0.90, 95% CI = 0.71–0.97). Considering change-of-direction performance, moderate reliability was observed for the non-dominant leg (ICC = 0.83, 95% CI = 0.63–0.94), while good reliability was observed for the dominant leg (ICC = 0.93, 95% CI = 0.83–0.98). Table 3 presents descriptive statistics for pre- and post-intervention measurements and the corresponding differences, categorized by group adherence with provided effect size for pre-post differences.

Results of mixed-design ANOVA (group × time) revealed a significant main effect of time for the COD test on the non-dominant leg ($p = 0.01$). Significant group × time interactions were observed for PP ($p = 0.01$) and BJ performance ($p = 0.03$). All observed differences were considered large based on $\eta^2_p \geq 0.14$ (Table 4).

Follow-up post-hoc comparisons for outcomes with statistically significant interaction effects did not reveal significant within- or between-group differences for peak power (all $p > 0.05$). Nevertheless, the magnitude of change in the IST-CT group indicated a small effect size (Hedges' $g = 0.54$). Likewise, although the interaction effect for the BJ reached significance in the ANOVA, the subsequent post-hoc comparisons did not identify significant within- or between-group differences (all $p > 0.05$). The pre-to-post change in the IST-CT group demonstrated a small effect size (Hedges' $g = 0.29$), despite not reaching statistical significance. Although the interaction effects in the ANOVA reached statistical significance, the follow-up post-hoc comparisons did not identify significant pairwise differences. This pattern is consistent with situations in which ANOVA detects overall group × time divergence, while post-hoc tests, especially when corrected for multiple comparisons, may lack sufficient statistical power to resolve specific contrasts within smaller sample subgroups. Reporting the corresponding effect sizes provides an additional context regarding the magnitude and direction of observed changes, even in the absence of statistically significant pairwise results.

Furthermore, based on the smallest worthwhile change (SWC), individuals were classified as responders (RS) and non-responders (NRS), and the frequency of improvement or its absence was assessed using the chi-square and Fisher's exact tests (Table 5). Signal-to-noise ratio (SNR) values ranged from 0.49 to 2.22 across all analyzed variables. In most performance outcomes, including the RSI, PP, BJ, and CMJ under the CT condition, the SNR exceeded the threshold of 1.0, indicating that the adopted SWC values were larger than the typical measurement error and thus reliable for identifying meaningful responses. Conversely, some variables—such as COD performance with the dominant leg—showed SNR values below 1.0, suggesting that responder classifications for these measures should be interpreted with caution.

For CMJ height, and PP, a greater number of responders was observed under the IST-CT condition compared to CT; however, these differences did not reach statistical significance (CMJ: $\chi^2 = 0.68$, $p = 0.41$; Fisher's $p = 0.68$; peak power: $\chi^2 = 1.60$, $p = 0.22$; Fisher's $p = 0.40$). A similar trend was seen in the BJ, with five responders performing IST-CT versus two performing CT ($\chi^2 = 1.81$, $p = 0.18$; Fisher's $p = 0.37$). For the RSI, the number of responders was identical in both protocols (6 vs. 6), yielding no difference between groups ($\chi^2 = 0.00$, $p = 1.00$; Fisher's $p = 1.00$). In the 30-m sprint and COD tests, no significant between-group differences were observed in responder frequency (all $p > 0.61$).

Table 1. Exercise selection and loading variables for the complex training program with additional run-specific isometric exercises.

Phase 1							
Weeks 1–2					Weeks 3–4		
Exercise		Sets	Reps	Intensity	Sets	Reps	Intensity
1a	Ankle ISO (Bend knee)	2–3	3 x 5"	100% MVIC	3	5 x 3"	100% MVIC
1b	Knee ISO	2–3	3 x 5"	100% MVIC	3	5 x 3"	100% MVIC
1c	Hip ISO (90)	2–3	3 x 5"	100% MVIC	3	5 x 3"	100% MVIC
2a	Box squat	2–3	6	75% 1RM	4	3	85% 1RM
2b	Drop jump (30–45 cm)	2–3	3	-	4	3	-
3a	Bench press	2–3	6	75% 1RM	4	3	85% 1RM
3b	Plyo push up	2–3	5	-	4	5	-
4a	Single arm dumbbell row	2–3	10	RPE8	3	6	RPE8
4b	Single leg dumbbell RDL	2–3	10	RPE8	3	6	RPE8
4c	Cable rotations	2–3	10	RPE8	3	6	RPE8
Phase 2							
Weeks 5–6					Weeks 7–8		
Exercise		Sets	Reps	Intensity	Sets	Reps	Intensity
1a	Ankle ISO (Straight knee)	2–3	6 x 2"	100% MVIC	3	9 x 1"	100% MVIC
1b	Knee ISO	2–3	6 x 2"	100% MVIC	3	9 x 1"	100% MVIC
1c	Hip ISO (120)	2–3	6 x 2"	100% MVIC	3	9 x 1"	100% MVIC
2a	Banded box squat	3	4	60% 1RM + 25kg band	4	2–3	70% 1RM + 25kg band
2b	Drop jump + hurdle jump (60–80 cm)	3	3	-	4	3	-
3a	Banded bench press	3	4	60% 1RM + 25kg band	4	2–3	70% 1RM + 25kg band
3b	Plyo push up (band assisted)	3	5	-	4	5	-
4a	Bird dog row	3	8	RPE8	3	5	RPE8
4b	Single leg dumbbell RDL (fast eccentric)	3	8	RPE8	3	5	RPE8
4c	Medicine ball rotational throw	3	5	4 kg	3	5	6 kg

Table 2. Exercise selection and loading variables for the complex training program.

Phase 1							
Weeks 1–2					Weeks 3–4		
Exercise		Sets	Reps	Intensity	Sets	Reps	Intensity
1a	Box squat	2–3	6	75% 1RM	4	3	85% 1RM
1b	Drop jump (30–45 cm)	2–3	3	-	4	3	-
2a	Bench press	2–3	6	75% 1RM	4	3	85% 1RM
2b	Plyo push up	2–3	5	-	4	5	-
3a	Single arm dumbbell row	2–3	10	RPE8	3	6	RPE8
3b	Single leg dumbbell RDL	2–3	10	RPE8	3	6	RPE8
3c	Cable rotations	2–3	10	RPE8	3	6	RPE8

Phase 2							
Weeks 5–6					Weeks 7–8		
Exercise		Sets	Reps	Intensity	Sets	Reps	Intensity
1a	Banded box squat	3	4	60% 1RM + 25kg band	4	2–3	70% 1RM + 25kg band
1b	Drop jump + hurdle jump (60–80 cm)	3	3	-	4	3	-
2a	Banded bench press	3	4	60% 1RM + 25kg band	4	2–3	70% 1RM + 25kg band
2b	Plyo push up (band assisted)	3	5	-	4	5	-
3a	Bird dog row	3	8	RPE8	3	5	RPE8
3b	Single leg dumbbell RDL (fast eccentric)	3	8	RPE8	3	5	RPE8
3c	Medicine ball rotational throw	3	5	4 kg	3	5	6 kg

Table 3. Descriptive statistics of the analyzed variables.

Variable	Group	Pre *M* ± *SD* (95%CI)	Post *M* ± *SD* (95%CI)	Δ*M* ± *SD* (95%CI)	ES Pre vs. Post (95%CI)
Countermovement jump [cm]	IST-CT	38.9 ± 3.8 (36.5–41.4)	40.2 ± 4.4 (37.4–43.0)	1.3 ± 3.3 (−0.9–3.4)	0.30 (−0.24–0.84)
	CT	37.6 ± 5.2 (34.3–40.9)	36.9 ± 3 (35.0–38.8)	−0.7 ± 3.9 (−3.2–1.8)	−0.15 (−0.68–0.38)
Peak power [W/kg]	IST-CT	53.96 ± 4.66 (51.00–56.92)	56.89 ± 5.63 (53.32–60.47)	2.93 ± 3.47 (0.73–5.14)	0.54 (−0.03–1.11)
	CT	54.15 ± 5.39 (50.73–57.57)	52.38 ± 3.04 (50.44–54.31)	−1.78 ± 4.42 (−4.58–1.03)	−0.37 (−0.92–0.17)
Modified Reactive Strength Index [m/s]	IST-CT	0.52 ± 0.09 (0.47–0.58)	0.51 ± 0.11 (0.44–0.57)	−0.02 ± 0.12 (−0.1–0.06)	−0.09 (−0.62–0.44)
	CT	0.50 ± 0.07 (0.45–0.54)	0.46 ± 0.06 (0.43–0.50)	−0.04 ± 0.05 (−0.06–0.01)	−0.57 (−1.14–0.01)
Broad jump [cm]	IST-CT	248.7 ± 15.2 (239.0–258.3)	253.3 ± 14.5 (244.1–262.6)	4.7 ± 5.8 (1–8.4)	0.29 (−0.25–0.83)
	CT	246.4 ± 10.8 (239.5–253.3)	244.5 ± 11.7 (237.1–252.0)	−1.9 ± 7.5 (−6.6–2.9)	−0.16 (−0.69–0.37)
30-m linear speed [s]	IST-CT	4.17 ± 0.17 (4.06–4.28)	4.15 ± 0.11 (4.08–4.21)	−0.02 ± 0.13 (−0.11–0.06)	−0.13 (−0.66–0.40)
	CT	4.22 ± 0.08 (4.17–4.27)	4.24 ± 0.12 (4.16–4.31)	0.02 ± 0.10 (−0.049–0.077)	0.19 (−0.35–0.72)
505 COD dominant leg [s]	IST-CT	2.29 ± 0.09 (2.22–2.35)	2.25 ± 0.08 (2.20–2.30)	−0.04 ± 0.10 (−0.11–0.02)	−0.45 (−1.00–0.11)
	CT	2.33 ± 0.04 (2.30–2.35)	2.31 ± 0.09 (2.25–2.36)	−0.02 ± 0.07 (−0.06–0.02)	−0.27 (−0.81–0.27)
505 COD non-dominant leg [s]	IST-CT	2.31 ± 0.10 (2.25–2.36)	2.25 ± 0.06 (2.21–2.29)	−0.05 ± 0.05 (−0.09 −0.02)	−0.68 (−1.27–0.09)
	CT	2.30 ± 0.08 (2.26–2.35)	2.29 ± 0.10 (2.23–2.36)	−0.01 ± 0.06 (−0.05–0.03)	−0.10 (−0.63–0.43)

Table 4. Results of two-way mixed-design ANOVA.

Variable	Factor	*F*	η^2_p	*P*
Countermovement jump [cm]	Group	2.20	0.09	0.15
	Time	0.15	0.01	0.70
	Group – time	1.73	0.07	0.20
Peak Power [W/kg]	Group	1.48	0.06	0.24
	Time	0.51	0.02	0.48
	Group – time	8.44	0.28	0.01*
Modified reactive strength index [m/s]	Group	1.43	0.06	0.24
	Time	2.04	0.08	0.16
	Group – time	0.20	0.01	0.65
Broad Jump [cm]	Group	1.12	0.05	0.30
	Time	1.04	0.05	0.32
	Group – time	5.73	0.21	0.03*
30m linear speed [s]	Group	2.59	0.11	0.12
	Time	0.05	0.00	0.82
	Group – time	0.67	0.03	0.42
505 COD dominant leg [s]	Group	4.47	0.18	0.05
	Time	3.65	0.15	0.07
	Group – time	0.46	0.02	0.51
505 COD non-dominant leg [s]	Group	0.34	0.02	0.56
	Time	7.06	0.24	0.01*
	Group – time	3.01	0.12	0.10

* *statistically significant difference $p < 0.05$*

The red color was used to highlight statistically significant differences

Table 5. Distribution of responders (RS) and non-responders (NRS) across performance metrics, including chi-square and Fisher's exact test results with corresponding effect sizes (Cramér's *V*).

Variable	CT-IST			CT			χ^2	Cramér's *V*	*p*-value (χ^2)	*p*-value (Fischer)
	SNR	classification	n	SNR	classification	n				
Countermovement jump	0.98	RS	6	1.13	RS	4	0.68	0.17	0.41	0.68
		NRS	6		NRS	8				
Peak power	1.14	RS	6	1.03	RS	3	1.6	0.27	0.22	0.40
		NRS	6		NRS	9				
Modified reactive strength index	1.27	RS	3	1.16	RS	3	0.00	0.00	1.00	1.00
		NRS	9		NRS	9				
Broad jump	2.22	RS	5		RS	2	1.81	0.27	0.18	0.37
		NRS	7	1.22	NRS	10				
30-m linear speed	1.11	RS	3	0.68	RS	2	0.25	0.10	0.61	1.00
		NRS	9		NRS	10				
505 COD dominant leg	0.76	RS	5	0.49	RS	6	0.16	0.08	0.68	1.00
		NRS	7		NRS	6				
505 COD non-dominant leg	1.70	RS	6	1.13	RS	5	0.16	0.08	0.68	1.00
		NRS	6		NRS	7				

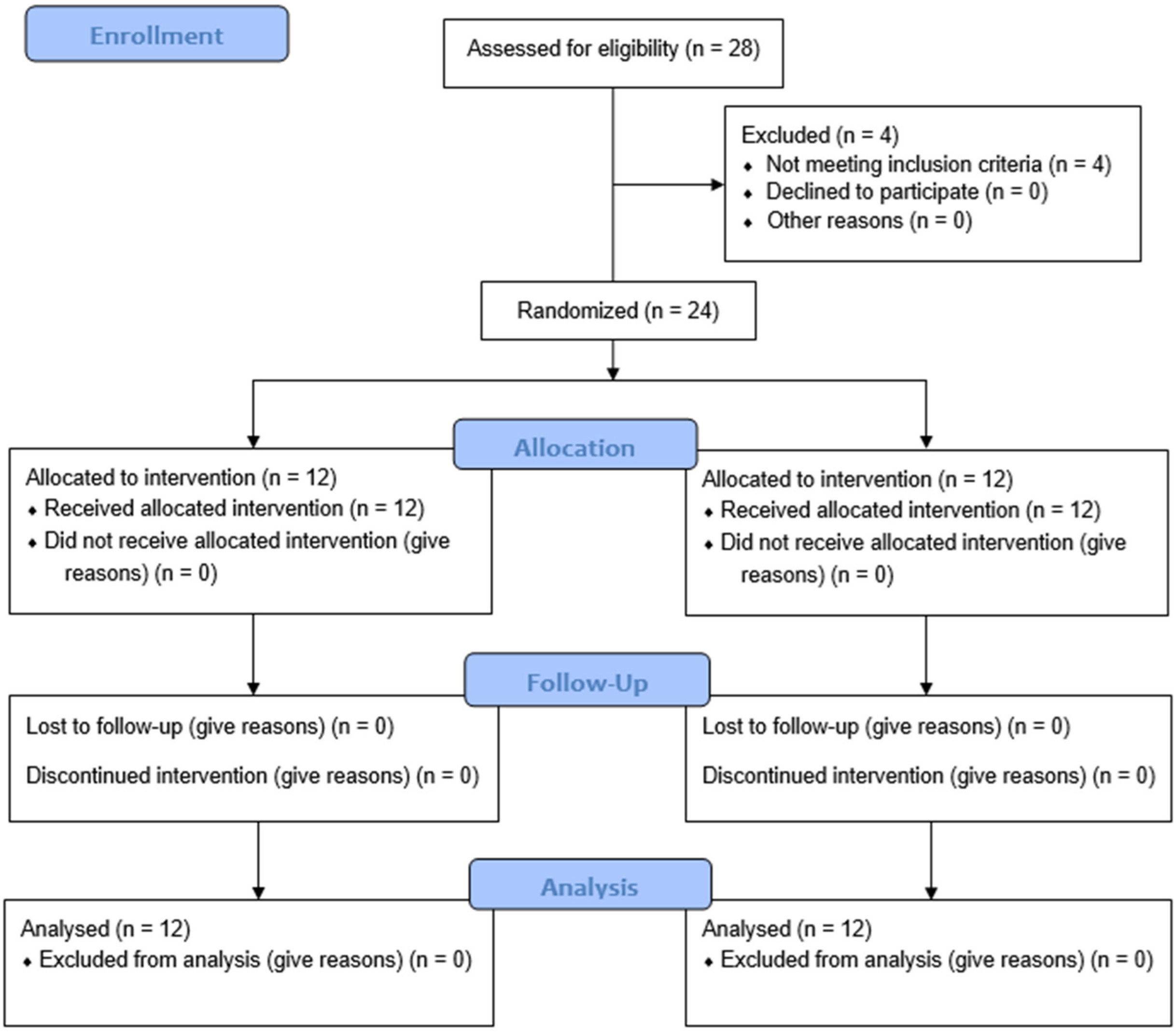

Figure 1. Participants' flow diagram.

Discussion

The aim of this study was to compare the effects of a CT program preceded by an IST-CT block with a traditional CT protocol during the in-season period on neuromuscular performance of youth soccer players. Contrary to our initial hypothesis, which assumed that IST-CT would lead to superior improvements, the results did not confirm significant between-group differences. Both interventions, however, demonstrated potential to enhance strength-speed qualities. A significant interaction effect was identified for PP and BJ performance, with the IST-CT group presenting a more favorable trend that did not translate into statistically significant pairwise differences. Additionally, a significant main effect of time was observed for non-dominant-leg 505 COD performance (p = 0.01), whereas the group effect for dominant-leg 505 COD performance was borderline (p = 0.05)., suggesting that both training protocols were able to influence these specific performance components irrespective of the group allocation. Although the magnitude of several effect sizes and the distribution of responders pointed toward slightly more favorable adaptations in the IST-CT group, these patterns cannot be regarded as conclusive evidence and should be interpreted with caution given the absence of statistically significant within- or between-group differences.

Nevertheless, although CT is widely recognized as an effective intervention for improving strength-speed abilities in soccer players (Cormier et al., 2022), evidence among young populations appears to indicate limited or inconsistent effects. These discrepancies have often been attributed to differences in maturational status and neuromuscular development (Kraemer and Ratamess, 2005). Although maturation-related variation is particularly relevant during early and mid-adolescence, the players in the present study were 18–19 years old which is the age at which most individuals have completed peak height velocity and attained near-adult neuromuscular and hormonal profiles (Malina et al., 2015). Consequently, maturational variability was likely attenuated relative to younger cohorts and is unlikely to represent a primary determinant of the modest training responses observed. The present findings therefore contrast with previous research conducted in less mature samples (Barra-Moura et al., 2024), where ongoing biological development may have constrained adaptive potential.

Another explanation for the limited improvements may relate to the seasonal timing of the intervention. The training intervention was implemented during the in-season period, when players typically maintain high levels of physical performance and may display reduced capacity for further performance enhancement. This phenomenon reflecting diminishing returns in highly trained athletes (Tier 3), even at late-adolescent ages may have contributed to the modest or non-significant changes observed. Similar observations were reported by Krzysztofik et al. (2025) who found that although a 6-week CT intervention elicited improvements in selected performance outcomes, it did not augment the magnitude of PAPE responses in CMJ performance. These findings support the notion that gains in physical performance do not necessarily translate directly into enhanced acute potentiation effects.

It is also worth considering the potential mechanisms that may underlie these responses. Recent evidence suggests that rapid isometric contractions, such as those used in RSIso, can enhance PAPE effect by increasing neuromuscular drive and motor unit recruitment efficiency (Blazevich et al., 2020; Pereira et al., 2025). In particular, isometric tasks performed with the explicit intent of rapid force production appear to be effective in improving the rate of force development (RFD) both in early (0–50 ms) and late (0–200 ms) phases of contraction, which are critical for explosive athletic actions such as sprinting and jumping (Young and Bilby, 1993). This effect seems to be partly independent of the actual movement velocity, as the intent to contract as fast and forcefully as possible can substantially augment neural activation patterns (Behm and Sale, 1993; Tillin and Folland, 2014). Furthermore, a meta-analysis by Blazevich et al. (2020) highlights that movement pattern specificity also plays a role in optimizing RFD gains. In the context of our intervention, RSIso positions shared biomechanical similarity with sport-relevant tasks (e.g., acceleration or jump take-off angles), which may have contributed to the observed improvements. Importantly, isometric training has the advantage of inducing such neuromuscular adaptations with relatively low metabolic cost (Newham et al., 1995), thereby reducing the risk of accumulating fatigue during congested match schedules (Jarosz et al., 2025b). In contrast, traditional dynamic warm-up or resistance protocols may impose greater mechanical and metabolic stress, potentially limiting the ability to sustain repeated high-quality neuromuscular stimuli during the in-season period (Ryschon et al., 1997; Stotz et al., 2022). Taken together, these mechanisms suggest that RSIso may provide a unique balance of potentiation and fatigue management, facilitating acute performance enhancement and supporting long-term neuromuscular adaptation in youth soccer players. Nevertheless, given the absence of significant between-group effects in our study, these explanations remain speculative and should be viewed as hypotheses for future research rather than confirmed mechanisms.

Despite the findings obtained, several important limitations of the study must be acknowledged. Firstly, the study design did not include a control group that received no supplementary training, which constrains causal inference. Secondly, the outcome assessment did not include sport-specific performance indicators (e.g., soccer-related agility or ball-handling skills), which limits its validity. Moreover, no GPS-derived data from training sessions or official matches were analyzed, which constrains inferences related to running demands and fatigue. Furthermore, concerns may be raised because of the recruitment of participants from two different clubs. Although both teams competed at a comparable competitive level and no significant baseline differences were found between them, it cannot be entirely excluded that unmeasured contextual or coaching-related factors may have influenced individual training adaptations. Moreover, the restricted number of studies investigating RSIso implementation within CT protocols across multiple training sessions during the competitive season makes contextualization of the present findings difficult. Future research should therefore consider employing more precise methods, such as force plates or dynamometry, to better quantify isometric training intensity.

Conclusions

No statistically significant differences were observed between the two training interventions in the CMJ, PP, or BJ performance. Nevertheless, the direction of changes indicated potential improvements following the IST-CT condition. These findings suggest that incorporating IST-CT may be a promising strategy for targeting strength-speed qualities in youth soccer players. However, given the modest magnitude of observed effects, further research across different seasonal phases and with larger samples is required to confirm these effects and define their practical relevance.

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