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Soccer players' physical performance adaptations with four weeks isometric versus dynamic contrast training: a randomized controlled trial

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Abstract

This randomized controlled study aimed to compare the effects of isometric contrast training (ICT) versus dynamic contrast training (DCT) on the physical performance of soccer players. Tier 3 male soccer players (age: 22.8±1.7 yrs) were randomly assigned to ICT (n=10), DCT (n=10), and control group (CG; n=10). Intervention groups performed similar low-load ballistic exercises, although the ICT and DCT incorporated push-isometrics or dynamic resistance high-load exercises, respectively. Aside from interventions, the off-season soccer training load was the same for control and intervention groups. Before and after 4-week of intervention, data were collected for 10 m, 20 m, and 40 m linear sprints, change of direction speed (CODS), countermovement jump (CMJ), standing long jump (SLJ), and 300-yard shuttle run test (SRT). After adjusting for baseline differences, statistical analysis revealed significant differences in all performance variables (p<0.001-0.018). Compared to controls, both intervention groups improved 40 m linear sprint, CODS, CMJ, and SRT (all p<0.05), and ICT also improved 10 m and 20 m linear sprint, and SLJ (all p<0.05). Relatedly, ICT improved 10 m linear sprint (p=0.001) and SLJ (p<0.001) when compared to DCT. In conclusion, soccer players improve physical performance with contrast training, particularly after ICT.

Keywords: *plyometric exercise, team sports, football, muscle strength, resistance exercise*

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Introduction

Soccer (football) is an intermittent sport requiring numerous sub-maximal to maximal efforts during training and competitions (Stølen et al., 2005). When the players are not in ball possession, these efforts may include sprinting, changing directions, or vertical jumping (Stølen et al., 2005), which is essential for soccer players' performance (Stølen et al., 2005; Weldon et al., 2021). For example, linear sprinting is the most common football action before a goal (Haugen et al., 2014), and linear sprinting (acceleration and maximal speed) and

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change of direction ability can distinguish participants' performance levels (Haugen et al., 2014).

These performance abilities can be improved through different resistance training methods targeting the neuromuscular system (Silva et al., 2015; Thapa et al., 2021). One such method is contrast training, which incorporates two exercises of similar biomechanical movement but distinctly varying loads (high load and low load) in a set-by-set fashion (Thapa, Weldon, et al., 2024). This exercise combination has been reported to induce neuromuscular adaptations and improve performance abilities such as sprinting (within-group effect size [ES] = 0.67-2.65), jumping (within-group ES = 0.89), changing direction (within-group ES = 1.11-1.24), maximal strength (contrast training versus control ES = 1.30), particularly in soccer players (Thapa et al., 2021; Thapa et al., 2022). The improvements with contrast training are typically attributed to the exercises with varying loads and velocities (i.e., heavy resistance exercise at lower velocity and ballistic jump exercise at higher velocity), targeting a wide portion of the force-velocity curve (Thapa, Uysal, et al., 2024). Additionally, using high-load exercises prior to low-load exercises during contrast training might induce a post-activation performance enhancement effect (i.e., enhancement in voluntary muscular performance after a high-intensity [high-load] voluntary conditioning contraction) (Blazevich & Babault, 2019; Thapa, Weldon, et al., 2024).

Most contrast training interventions used dynamic high-load resistance exercises before low-load exercises (Thapa, Weldon, et al., 2024). However, an isometric high-load exercise before low-load exercises can also be used effectively (Bogdanis et al., 2019; García-Pinillos et al., 2014; Latorre Román et al., 2018). Indeed, isometric strength training induces lower fatigue and greater joint angle-specific strength compared to dynamic resistance training (Lum & Barbosa, 2019). Therefore, exploring this training method could offer new insights into strength development with minimal fatigue (Lum & Barbosa, 2019). Additionally, isometric strength training can improve sprinting and jumping performance (Lum & Barbosa, 2019), requiring little or no extra-expensive equipment. However, very few studies have used a combination of isometric and ballistic exercise (Bogdanis et al., 2019; García-Pinillos et al., 2014; Latorre Román et al., 2018). Male physical education students applied six weeks of contrast training with isometric leg press at joint angles of 85° versus 145° as the high-load exercise and countermovement jump (CMJ) as the low-load exercise and reported similar improvement in CMJ (effect size [ES] = 0.55 vs. 0.70) and maximal strength (ES = 0.69 vs. 0.66) (Bogdanis et al., 2019). Other studies applied contrast training using holding isometrics (or quasi-isometrics) performed with participants' own body mass and reported improved CMJ, drop jump, squat jump, linear sprint, and change of direction speed (CODS) in 8 years children after 10 weeks (Latorre Román et al., 2018), and improved CMJ, CODS, and soccer kicking velocity in young male soccer player (~15 years) after 12-week of intervention (García-Pinillos et al., 2014).

However, if isometric contrast training induces greater adaptive stimuli compared to dynamic contrast training remains unexplored. Using isometrics over dynamic resistance exercise as a high-load exercise may have potential benefits with athletes without resistance training experience or athletes undergoing rehabilitation from injuries (Lum & Barbosa, 2019). Therefore, this study aimed to compare the effects of contrast training using push-isometrics versus dynamic resistance exercises as the high-load activity and similar ballistic jumps as the low-load activity on CODS, CMJ, linear sprints, standing long jump (SLJ) and anaerobic endurance (300-yard shuttle run test) performance of soccer players. Based on the literature (Bogdanis et al., 2019; Lum & Barbosa, 2019; Thapa, Weldon, et al., 2024), the authors hypothesized that both contrast training with isometric and dynamic resistance exercises would induce similar improvement in physical performance variables compared to the control condition.

Methods

Experimental approach to the problem

Following the CONSORT guidelines (Schulz et al., 2010), a two (within-subject; pre-post) by three (between-subject; isometric contrast training, dynamic contrast training, and control group) randomized controlled study design was conducted to compare the effects of two different contrast training interventions on physical performance measures. The pre- and post-intervention assessments were conducted at similar times of the day, with 48 hours of rest between assessments and the last training session. Furthermore, the sequence of tests performed by the participants was the same across both the pre- and post-intervention assessments.

Participants

The sample size for the study was estimated using a priori analysis (G power software, version 3.1.9.7). A sample size of 27 participants (9 in each group) was required for the study to find statistical significance in within-between interaction with three groups and two measurements (i.e., pre- and post-test), an alpha error probability of 0.05, a moderate effect size (f=0.26, calculated from Cohen d = 0.53) (Miranda et al., 2021), power of 0.80, correlation of 0.7 and nonsphericity correction of 1.

Thereafter, using a snowball sampling method, 30 male soccer players were recruited for the study. Basic anthropometric and age information of the participants are provided in Table 1.

Participants were classified as Tier 3 (i.e., highly trained) soccer players aged 18 to 25 years who participated in the state premier league (i.e., the top division league of a region). Participants had no record of recent injuries that could limit the

Table 1. Age and anthropometric characteristics of the participants before intervention.

Variables	ICT group (n=10)	DCT group (n=10)	Control group (n=10)	ANOVA P value
	Mean ± standard deviation			
Age (yr)	22.1±1.5	23.3±1.4	23.2±1.7	0.162
Height (cm)	174.2±5.4	175.7±6.5	172±5.1	0.356
Body mass (kg)	63.7±6.6	65.2±5.7	61.2±5.5	0.331
1RM squat (kg)	143.5±11.0	143.6±10.8	–	0.984*
Relative squat	2.3±0.2	2.2±0.1	–	0.484*

Note: * independent t test, ANOVA – analysis of variance, ICT – isometric contrast training, DCT – dynamic contrast training.

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execution of the exercises and tests. Additionally, the participants were required to be involved in regular soccer training in the past 6 months and willing to attend all the training sessions of the intervention. The exclusion criteria involved excluding individuals with recent injuries and not willing to participate in the intervention. The recruited participants were then randomly assigned (using the online tool: randomizer.org) to the three groups using a 1:1:1 allocation ratio. Due to the nature of the study, blinding was precluded for participants and researchers. The participants were explained the training protocol, its benefits, and potential risks associated with the study. After that, the participants signed informed consent forms. The study was approved by the Institutional Review Committee of Amity School of Physical Education and Sports Sciences and was conducted according to the principles in the Declaration of Helsinki.

Training intervention

The recruitment of participants was ongoing during the competitive season. However, the training intervention started during the off-season, two weeks after the competitive season ended. To replicate real-world schedules (i.e., ecological validity), and based on previous studies reporting favorable effects (Thapa et al., 2021; Thapa, Weldon, et al., 2024), the training intervention lasted four weeks with two weekly training sessions. The contrast pair of exercises were selected based on biomechanically similar movements (e.g., squat paired with a vertical jump) (Scott, Ditroilo, et al., 2023; Thapa, Weldon, et al., 2024). The intra-contrast rest between the alternating load was <30 s, and the between-set and between-contrast exercise recovery was 120 s. The nature of rest was always passive. For the isometric contrast training group, the exercises selected were 90° isometric squats paired with the vertical jump from a seated position and single-leg isometric quarter squats paired with a single-leg repeated broad jump. The push-isometric (or overcoming isometric) with maximal intent was used as the isometric form of exercise. The exercises selected for the dynamic contrast training group were squat paired with vertical jump from a seated position and deadlift paired with single-leg repeated broad jump. The one-repetition maximum (RM) for both squat and deadlift was estimated with 3RM assessments. The 1RM of the dynamic contrast training group was 143.6±10.8 kg for squats and 170.7±11.5 kg for the deadlifts. The progression was applied by increasing the duration of isometric contraction, percentage of one repetition maximum, number of jumps performed, and number of sets performed. The training sessions were conducted by a Certified Strength and Conditioning Specialist coach, who was not blinded to the interventions. Aside from interventions, the off-season soccer training load was the same for control and intervention groups. The control group did not engage in any form of resistance training. Interventions are detailed in Table 2.

Table 2. Training protocol used during both the interventions.

Week (session)	Combinations of exercise*	Set × recovery
1st (1-2)	90° isometric squat (6 s) / 90° dynamic squat (6 reps at 70-75% of 1 RM) + vertical jump from a seated position (6 reps), single leg isometric quarter squat (6 s) / deadlift (6 reps at 70-75% of 1 RM) + single leg repeated broad jump (6 reps)	4×120 s 4×120 s
2nd (3-4)	90° isometric squat (7 s) / 90° dynamic squat (6 reps at 75-80% of 1 RM) + vertical jump from a seated position (7 rep), single leg isometric quarter squat (7 s) / deadlift (6 reps at 75-80% of 1 RM) + single leg repeated broad jump (7 reps)	4×120 s 4×120 s
3rd (5-6)	90° isometric squat (8 s) / 90° dynamic squat (6 reps at 80-85% of 1 RM) + vertical jump from a seated position (8 reps), single leg isometric quarter squat (8 s) / deadlift (6 rep at 80-85% of 1 RM) + single leg repeated broad jump (8 reps)	5×120 s 5×120 s
4th (7-8)	90° isometric squat (10 s) / 90° dynamic squat (6 reps at 80-85% of 1 RM) + vertical jump from a seated position (10 reps), single leg isometric quarter squat (10 s) / deadlift (6 reps at 80-85% of 1 RM) + single leg repeated broad jump (10 reps)	5×120 s 5×120 s

Note: RM – repetition maximum; reps – repetitions.

Performance assessments

Independent assistants, blinded to the groups' allocation of participants, conducted the assessments.

Linear sprint times

The linear sprint times were recorded for 10 m, 20 m, and 40 m linear sprint times using a reliable timing system (Cronox-Sports, Madrid, Spain) (Thapa, Sarmah, et al., 2023). Based on previous research (Thapa, Sarmah, et al., 2023), the height of the photocell was set at 0.6 m above the ground level (i.e., approximate hip height) to avoid early start due to arm swing, and the participant started 0.3 m behind the first photocell with a standing stance. The participants were allowed to self-select their leading and rear legs and were instructed to start when they were ready. Two maximal effort trials were conducted with an inter-trial recovery of 1 min. The fastest time was selected for analyses.

Countermovement jump height

The CMJ was conducted to assess the vertical jumping ability and was performed on a reliable contact mat (Chronojump Bosco System) (Bagchi et al., 2024). Participants were instructed to jump as high as possible following a countermovement with a self-selected magnitude of knee flexion. Flexion of the knee was not allowed during the flight phase of the jump. Two maximal effort trials were conducted with an inter-trial recovery of 1 minute. The highest jump was selected for analysis.

Standing long jump

The SLJ was conducted to assess horizontal jumping ability and was performed on a firm surface in a gym with a measuring tape attached to the ground. Participants stood behind a marked line with their feet shoulder-width apart and performed the jump using a two-footed take-off with an arm swing. The participants were instructed to jump as far as possible and land on both feet without losing balance. The jump distance was measured from the take-off line to the nearest heel to the marked line after landing. Two maximal effort trials were conducted with an inter-trial recovery of 1 minute. The longest distance was selected for analysis.

Change of direction speed time

The pro-agility test was conducted to assess the CODS, which is a reliable test for CODS (Stewart et al., 2014). The test was conducted on a set-up with three lines separated 5 yards (4.6 m) apart. The participants started from the center line in a three-point position with feet shoulder-width apart and placed equally on either side of the line. The participants started by sprinting 5 yards to one side and touching the line with their lead foot and hand. Thereafter, participants sprinted 10 yards to the opposite line and touched the line with their lead foot and hand and finished by sprinting 5 yards back to the starting line. The participants were allowed to self-select the direction of the start. Two trials were conducted with an inter-trial recovery of 3 minutes. The fastest trial was selected for the analysis.

300-yard shuttle run

The 300-yard shuttle run test was used to assess the participants' short-duration high-intensity endurance, involving repeated sprints with a change of direction. Two markers were placed 25 yards apart, and participants started from one marker, sprinted to the opposite marker, touched the line, and sprinted back. The participants were required to complete 12 total lengths (6 round trips) for a total of 300 yards as fast as possible. An experienced timekeeper recorded the times using a hand-held stopwatch. After 1-2 submaximal practice trials, one maximal effort trial was conducted and used for the analysis.

Statistical analysis

The normal distribution of the data was assessed using the Shapiro-Wilk test. Normally distributed data are presented as means and standard deviation, while non-normally distributed data are presented as median and interquartile range. A two-way transformation was applied to non-normally distributed data (to normal) to perform parametric tests (Templeton, 2011). A two (within-group: pre- and post-) by three (between group: isometric contrast training, dynamic contrast training, control group) mixed design analysis of variance was used to analyze the exercise-specific effects on the dependent variables. Further, post-hoc analysis using Bonferroni correction was conducted to find the differences. Partial eta squared and Hedge's g effect sizes were also calculated to find the magnitude of differences. Partial eta squared were interpreted as small (<0.06), moderate (≥0.06-0.13), and large (≥0.14) (Cohen, 1988), and Hedge's g were interpreted as trivial (<0.2), small (0.2-0.6), moderate (>0.6-1.2), or large (>1.2-2.0) (Hopkins et al., 2009). Additionally, the reliability of the testing procedures was assessed using the intraclass correlation coefficient (ICC) between trials and was interpreted as poor (<0.5), moderate (0.5-0.75), good (0.75-0.9), and excellent (>0.9) reliability based on the lower bound of the 95% CI (Koo & Li, 2016). The statistical significance was set at p≤0.05.

Results

The training adherence of the participants was 100%, with no attrition. In addition, no participants reported any adverse effects due to the intervention. The measurements for the dependent variables showed good to excellent reliability based on the lower bound of the 95% CI (Table 3).

Table 3. Interclass correlation coefficient (ICC) with 95% confidence interval (CI).

Variables	ICC (95%CI)
10 m sprint time	0.84 (0.74-0.91)
20 m sprint time	0.96 (0.93-0.98)
40 m sprint time	0.98 (0.97-0.99)
Change of direction speed	0.88 (0.79-0.93)
Countermovement jump	0.96 (0.94-0.98)
Standing long jump distance	0.95 (0.92-0.97)

Table 4. Statistical comparisons between experimental and control groups.

	Isometric contrast training group (n = 10)			Dynamic contrast training group (n = 10)			Control group (n = 10)			ANCOVA
	Pre-test	Post-test	p-value	Pre-test	Post-test	p-value	Pre-test	Post-test	p-value	p-value [ηp²]
	Mean ± SD			Mean ± SD			Mean ± SD			
10 m sprint time (s)	2.06±0.09	2.00±0.06[ab]	<0.001	2.08±0.11	2.05±0.11[a]	<0.001	2.07±0.11	2.06±0.11[b]	0.082	<0.001 [0.57]
20 m sprint time (s)	3.16±0.17	3.06±0.18[b]	<0.001	3.01±0.25	3.01 (0.54)*	0.192	3.29±0.20	3.28±0.19[b]	0.569	<0.001 [0.54]
40 m sprint time (s)	5.38±0.33	5.27±0.28[b]	<0.001	5.51±0.40	5.41±0.38[c]	<0.001	5.57±0.39	5.61±0.40[bc]	0.054	<0.001 [0.62]
Change of direction speed (s)	4.91±0.08	4.84±0.07[b]	0.251	4.78±0.21	4.78±0.21[c]	0.579	4.94±0.26	5.08±0.31[bc]	0.034	0.018 [0.27]
CMJ (cm)	45.2±3.6	47.3±3.9[b]	<0.001	46.3±5.43	47.9±5.1[c]	<0.001	45.4±5.5	44.8±5.3[bc]	0.037	<0.001 [0.69]
SLJ distance (m)	2.27 (0.06)*	2.32 (0.09)*[ab]	<0.001	2.20±0.08	2.21±0.08[a]	0.417	2.23±0.12	2.23±0.10[b]	0.807	<0.001 [0.55]
300-yard shuttle run test (s)	56.7±1.7	56.07±1.69[b]	<0.001	55.9±2.5	55.9±2.3[c]	0.823	57.4±2.2	58.0±2.3[bc]	0.002	<0.001 [0.51]

Note: (i) Using pre-test scores as a covariate, the post-test scores were analyzed with the following interpretation: [a] – significant difference between the isometric contrast training group and the dynamic contrast training group; [b] – significant difference between the isometric contrast training group and the control group; and [c] – significant difference between the dynamic contrast training group and the control group. (ii) * data presented as median (interquartile range); CMJ – countermovement jump; ηp² – partial eta squared; SD – standard deviation; SLJ – standing long jump.

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Before interventions, all groups showed similar anthropometric, age (Table 1) and physical performance (Table 4). The results of the interventions are detailed in Table 4, with within-group Hedge's g effect size analyses detailed in Table 5 and a graphical representation of pre- to post-intervention percentage change in Figure 1.

Table 5. Effect size from pre- to post-intervention changes in each group.

Variables	ICT group (n = 10)	DCT group (n = 10)	Control group (n = 10)
10 m sprint time	0.75	0.26	0.09
20 m sprint time	0.55	0.23	0.05
40 m sprint time	0.34	0.25	0.10
Change of direction speed	0.89	0.00	0.47
Countermovement jump	0.54	0.29	0.11
Standing long jump distance	0.67	-0.12	0.00
300-yard shuttle run test	0.36	0.00	0.26

Note: DCT – dynamic contrast training, ICT – isometric contrast training.

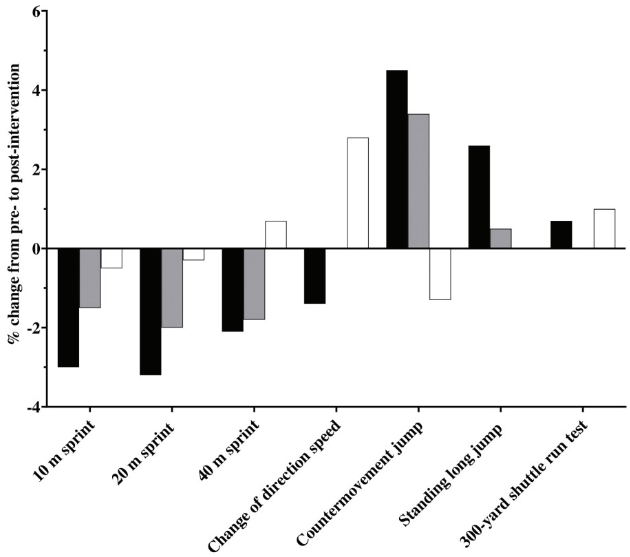

Figure 1. Graphical representation of pre- to post-intervention percentage change in outcome variables for each group. Note – black, gray, and white bars denote isometric contrast training, dynamic contrast training, and control groups, respectively.

Within-group analysis

Significant within-group improvements in the 10 m and 40 m linear sprint were observed for both the isometric contrast training (%Δ=2.1% to 3.0%) and dynamic contrast training (%Δ=1.5% to 1.8%) group (all p<0.001) but not in the control group (p=0.084-0.254, %Δ=0.5% to 0.7%). No within-group changes in CODS were observed for both isometric contrast and dynamic contrast training groups (p=0.251 - 0.579, %Δ=0.0% to 1.4%) and in the 20 m linear sprint for the dynamic contrast training group (p=0.192, %Δ=2.0%). Moreover, the control group decreased CODS performance (p=0.034, %Δ=2.8%). For CMJ, within-group improvements were observed in both training groups (both p<0.001, %Δ=3.4% to 4.5%), whereas a decline in CMJ performance was observed for the control group (p=0.037, %Δ=1.3%).

Between-group analysis

A significant difference at post-intervention using the pre-intervention scores as covariates was observed for 10 m (F=17.4, p<0.001), 20 m (F=15.3, p<0.001), 40 m (F=20.8, p<0.001), CODS (F=3.6, p=0.041) countermovement jump (F=22.9, p<0.001), SLJ (F=15.4, p<0.001), and 300-yard shuttle run test (F=14.5, p<0.001).

Furthermore, the covariate-adjusted scores at the post-test were 2.00±0.06 s, 2.05±0.11 s, and 2.06±0.11 s for isometric contrast training, dynamic contrast training, and control groups, respectively. The post hoc analysis revealed a significant difference between the isometric contrast training and dynamic contrast training groups (p=0.001) and the control group (p<0.001), favoring isometric contrast training. No difference was observed between dynamic contrast training and the control group (p=0.171).

For the 20 m linear sprint, the covariate-adjusted scores at the post-test were 3.06±0.18 s, 2.95±0.20 s, and 3.28±0.19 s for isometric contrast training, dynamic contrast training, and control groups, respectively. A significant difference was observed between isometric contrast training and the control group (p=0.005). No differences were observed between the dynamic contrast and isometric contrast training group (p=0.066) and the control group (p=0.452).

For the 40 m linear sprint, the covariate-adjusted scores at the post-test were 5.27±0.28 s, 5.41±0.38 s, and 5.61±0.37 s for isometric contrast training, dynamic contrast training, and control groups, respectively. Significant differences were observed between isometric contrast training and control group (p<0.001) and dynamic contrast training and control group (p<0.001). No differences were observed between isometric and dynamic contrast training (p=1.000).

For the CODS, the covariate-adjusted scores at the post-test were 4.84±0.07 s, 4.78±0.21 s, and 5.08±0.31 s for isometric contrast training, dynamic contrast training, and control groups, respectively. Significant differences were observed between isometric contrast training and the control group (p=0.035) and dynamic contrast training and the control group (p=0.045). No difference was observed between isometric and dynamic contrast training (p=1.000).

For the CMJ, the covariate-adjusted scores at post-test were 47.3±3.9 cm, 47.9±5.1 cm, and 44.8±5.3 cm for isometric contrast training, dynamic contrast training, and control groups, respectively. Significant differences were observed between isometric contrast training and control group (p<0.001) and dynamic contrast training and control group (p<0.001). No difference was observed between the isometric and dynamic contrast training groups (p=0.657).

For the SLJ, the covariate-adjusted scores at the post-test were 2.31±0.08 m, 2.21±0.08 m, and 2.23±0.10 m for isometric contrast training, dynamic contrast training, and control groups, respectively. Significant differences were observed between the isometric contrast training and dynamic contrast training group (p<0.001) and the control group (p<0.001). No differences were observed between dynamic contrast training and the control group (p=1.000).

For the 300-yard shuttle run test, the covariate-adjusted scores at the post-test were 56.1±1.7 s, 55.9±2.3 s, and 58.0±2.3 s for isometric contrast training, dynamic contrast training, and control groups, respectively. Significant differences were observed between isometric contrast training and control group (p<0.001) and dynamic contrast training and control group (p=0.033). No difference was observed between isometric and dynamic contrast training (p=0.081).

Discussion

Soccer players improved physical performance with the incorporation of contrast training during the off-season period, particularly when isometric exercises were used as the heavy-load exercise pair during contrast training sessions.

The improvements observed in linear and non-linear sprints and jumping performance after contrast training are in line with previous studies conducted on soccer players (Kumar, Pandey, Ramirez-Campillo, et al., 2023; Thapa, Kumar, Raizada, et al., 2023; Thapa et al., 2021) and other athletes/participants (Kumar, Pandey, Thapa, et al., 2023; Thapa & Kumar, 2023; Thapa, Kumar, Weldon, et al., 2023). However, the magnitude of the improvements differed from previous studies (e.g., small versus moderate improvements in 40 m linear sprint time and CMJ) (Kumar, Pandey, Ramirez-Campillo, et al., 2023; Thapa, Kumar, Raizada, et al., 2023), possibly due to the variation in training duration (i.e., 4 weeks versus 6 weeks). Contrast training can induce a myriad of adaptations potentially relevant for improved sprinting and jumping performance, such as increased maximal strength (Thapa et al., 2022), free testosterone (Ali et al., 2019), and improved muscle architecture (e.g., muscle thickness, fascicle length) (Scott, Marshall, et al., 2023). Contrast training can also improve neuromuscular function through a wide range of the force-velocity curve (Cormier et al., 2022; Thapa, Kumar, Raizada, et al., 2023; Thapa, Weldon, et al., 2024). For example, the ballistic exercises included in contrast training sessions can increase power and rate of force development, in line with adaptations such as improved motor unit firing rate, recruitment patterns, and intra- and inter-muscular coordination (Zehr & Sale, 1994). Contrast training also can induce greater preservation of fast-twitch muscle fibers (Stasinaki et al., 2015) - particularly relevant effect during the off-season - possibly due to ballistic exercises inducing greater stimulation (e.g. micro damage) of type II muscle fibers (Macaluso et al., 2012). Indeed, type II muscle fibers are characterized by a high contraction velocity, rate of force development, and power, key traits during sprinting and jumping (Powers & Howley, 2018). Additionally, exercise specificity may be another plausible reason that has led to a better transference effect through motor learning as the ballistic exercises used in the intervention, as well as sprinting and jumping, both utilize the stretch-shortening cycle muscle action (Stone et al., 2022). Moreover, ballistic exercises during contrast training may improve mechanical properties of the muscle-tendon complex (Kubo et al., 2007) and reactive strength (Ramirez-Campillo et al., 2023), the later associated with sprinting and jumping ability (Jarvis et al., 2022).

Our findings suggest that isometric contrast training may be more effective for short sprints and SLJ, adding to the growing body of evidence supporting its benefits (Thapa, Weldon, et al., 2024). Pushing isometrics in a contrast training format might increase the maximal force production at specific trained joint angles (i.e., 90°) compared to dynamic exercise (Folland et al., 2005). Since the participants started the linear sprint test using a standing start, it may be possible that isometric exercise provided an advantage over dynamic exercise by improving the ability to generate high force from a stationary start (Brady et al., 2020). Indeed, in a previous study, the authors reported isometric squat strength to be associated with 5 m sprint time after a block start in sprinters (r=0.714) but not with sprint distance >10 m (Brady et al., 2020). It may also be possible that the biomechanical specificity of sprinting affected the timings after both training protocols. The 10 m sprint distance includes the drive phase with longer ground contact times (compared to the later stage of sprinting), which mainly relies on horizontal force production with more force application at particular joint angles and greater emphasis on net concentric power generation (Wild et al., 2011). In the later stages of the sprinting distance, the ground contact time decreases, and the shift focuses on net eccentric power dissipation with greater emphasis on vertical ground reaction forces (Wild et al., 2011), which may have resulted in no difference in 20 m and 40 m sprint times. Therefore, athletes have more time to apply force during ground contact up to 10 m distance, thus benefiting from isometric contrast training.

Regarding SLJ, a significant difference was observed for SLJ favoring isometric contrast training over dynamic contrast training. Previous studies reported that amateur (i.e., Tier 2) athletes improved SLJ performance after 4 weeks of dynamic contrast training (Dodd & Alvar, 2007; Kumar, Pandey, Ramirez-Campillo, et al., 2023; Thapa, Kumar, Raizada, et al., 2023; Thapa, Kumar, Weldon, et al., 2023), although did not compared to higher-level athletes. Therefore, current findings add to the body of knowledge, suggesting greater benefits of isometric versus dynamic contrast training. Of note, a significant decline was observed in the 300-yard shuttle run test in the control group, but not in the contrast training groups. This suggests that both contrast training formats can help in miti-

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gating the detraining effects during the off-season period. The 300-yard shuttle run test performance involves multiple rapid accelerations, decelerations, and change-of-directions, requiring high eccentric and concentric force application, that may have improved after contrast training, but not in control condition (Wilson et al., 1996).

One of the strengths of this study was the 100% adherence to the interventions noted by the participants. This probably contributed to the effectiveness of the interventions, although reasons (e.g., short intervention duration; accredited coaches) for such elevated adherence are not clear. However, aside from its strengths, there are a few potential limitations of the study that should be acknowledged. Firstly, the study was conducted during the off-season period, and therefore, the training outcomes could be different during the pre- and in-season periods due to additional training stimulus from soccer-specific practice. Secondly, the participants were highly trained (Tier 3) male soccer players. How untrained (Tier 1), trained (Tier 2), elite (Tier 4), or world-class (Tier 4) male or female participants would respond to these contrast training methods needs further investigation. Thirdly, the physical performance measures (e.g., CMJ) involved field-based methods (e.g., contact mat). Including more sophisticated measurement instruments (e.g., force platforms) could provide a more comprehensive biological-biomechanic understanding of the adaptations after contrast training. Fourthly, total training load (e.g., session rating of perceived exertion × session duration) was not assessed. Lastly, the study was limited to a 4-week duration. Future studies should confirm if these findings are sustained over a longer duration (e.g., ≥8 weeks).

Conclusion

This is the first study that compared contrast training performed with push-isometrics or dynamic resistance exercise as the high-load activity. The study findings showed isometric contrast training to be similar (or better) compared to dynamic contrast training in improving the linear sprints (10 m, 20 m, and 40 m), CMJ, and SLJ performance of trained male soccer players. In addition, the CODS and 300-yard shuttle run test performance could be sustained via both contrast training methods, while the control group had a decline in performance. Coaches and practitioners may use both isometric or dynamic contrast training during the off-season period to retain (or even improve) the performance of the soccer players. Indeed, dynamic contrast training can be replaced with isometric contrast training to maintain training variability. From a logistical point of view, isometric contrast training may also offer greater feasibility, particularly for groups of players with a wide range of strength levels (e.g., potentially safer for participants new to strength training and unable to perform dynamic resistance with minimal load) and/or for large groups of players (e.g., a large group of players can train using the same equipment [smith machine] without requiring frequent changes of load).

Author contributions

MD, RD, RRC, and RKT conceived and designed the study. MD was involved in the data collection process. RKT conducted the formal analysis of the data, created the figures, and wrote the first draft of the manuscript. MD, RD, and RRC reviewed and revised the manuscript draft. All authors agree to publish the final version of the manuscript.

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Conflict of interest

None

Data availability

The data will be made available by the corresponding author upon reasonable request.

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References

Ali, K., Verma, S., Ahmad, I., Singla, D., Saleem, M., & Hussain, M. E. (2019). Comparison of complex versus contrast training on steroid hormones and sports performance in male soccer players. *J Chiropr Med*, *18*(2), 131-138. https://doi.org/10.1016/j.jcm.2018.12.001

Bagchi, A., Raizada, S., Thapa, R. K., Stefanica, V., & Ceylan, H. (2024). Reliability and accuracy of portable devices for measuring countermovement jump height in physically active adults: A comparison of force platforms, contact mats, and video-based software. *Life (Basel)*, *14*(11). https://doi.org/10.3390/life14111394

Blazevich, A. J., & Babault, N. (2019). Post-activation potentiation versus post-activation performance enhancement in humans: Historical perspective, underlying mechanisms, and current issues. *Front Physiol*, *10*, 1359. https://doi.org/10.3389/fphys.2019.01359

Bogdanis, G. C., Tsoukos, A., Methenitis, S. K., Selima, E., Veligekas, P., & Terzis, G. (2019). Effects of low volume isometric leg press complex training at two knee angles on force-angle relationship and rate of force development. *Eur J Sport Sci*, *19*(3), 345-353. https://doi.org/10.1080/17461391.2018.1510989

Brady, C. J., Harrison, A. J., Flanagan, E. P., Haff, G. G., & Comyns, T. M. (2020). The relationship between isometric strength and sprint acceleration in sprinters. *Int J Sports Physiol Perform*, *15*(1), 38-45. https://doi.org/10.1123/ijspp.2019-0151

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (Second ed.). Lawrence Erlbaum Associates.

Cormier, P., Freitas, T. T., Loturco, I., Turner, A., Virgile, A., Haff, G. G., Blazevich, A. J., Agar-Newman, D., Henneberry, M., Baker, D. G., McGuigan, M., Alcaraz, P. E., & Bishop, C. (2022). Within session exercise sequencing during programming for complex training: Historical perspectives, terminology, and training considerations. *Sports Med*, *52*(10), 2371-2389. https://doi.org/10.1007/s40279-022-01715-x

Dodd, D. J., & Alvar, B. A. (2007). Analysis of acute explosive training modalities to improve lower-body power in baseball players. *J Strength Cond Res*, *21*(4), 1177-1182. https://doi.org/10.1519/r-21306.1

Folland, J. P., Hawker, K., Leach, B., Little, T., & Jones, D. A. (2005). Strength training: Isometric training at a range of joint angles versus dynamic training. *J Sports Sci*, *23*(8), 817-824. https://doi.org/10.1080/02640410400021783

García-Pinillos, F., Martínez-Amat, A., Hita-Contreras, F., Martínez-López, E. J., & Latorre-Román, P. A. (2014). Effects of a contrast training program without external load on vertical jump, kicking speed, sprint, and agility of young soccer players. *J Strength Cond Res*, *28*(9), 2452-2460. https://doi.org/10.1519/jsc.0000000000000452

Haugen, T., Tønnessen, E., Hisdal, J., & Seiler, S. (2014). The role and development of sprinting speed in soccer. *Int J Sports Physiol Perform*, *9*(3), 432-441. https://doi.org/10.1123/ijspp.2013-0121

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise*, *41*(1), 3-13. https://doi.org/10.1249/MSS.0b013e31818cb278

Jarvis, P., Turner, A., Read, P., & Bishop, C. (2022). Reactive strength index and its associations with measures of physical and sports performance: A systematic review with meta-analysis. *Sports Med*, *52*(2), 301-330. https://doi.org/10.1007/s40279-021-01566-y

Koo, T. K., & Li, M. Y. (2016). A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *Journal of Chiropractic Medicine*, *15*(2), 155-163. https://doi.org/10.1016/j.jcm.2016.02.012

Kubo, K., Morimoto, M., Komuro, T., Yata, H., Tsunoda, N., Kanehisa, H., & Fukunaga, T. (2007). Effects of plyometric and weight training on muscle-tendon complex and jump performance. *Med Sci Sports Exerc*, *39*(10), 1801-1810. https://doi.org/10.1249/mss.0b013e31813e630a

Kumar, G., Pandey, V., Ramirez-Campillo, R., & Thapa, R. K. (2023). Effects of six-week pre-season complex contrast training intervention on male soccer players' athletic performance. *Polish Journal of Sport and Tourism*, *30*(3), 29-35.

Kumar, G., Pandey, V., Thapa, R. K., Weldon, A., Granacher, U., & Ramirez-Campillo, R. (2023). Effects of exercise frequency with complex contrast training on measures of physical fitness in active adult males. *Sports (Basel)*, *11*(1). https://doi.org/10.3390/sports11010011

Latorre Román, P., Villar Macias, F. J., & García Pinillos, F. (2018). Effects of a contrast training programme on jumping, sprinting and agility performance of prepubertal basketball players. *J Sports Sci*, *36*(7), 802-808. https://doi.org/10.1080/02640414.2017.1340662

Lum, D., & Barbosa, T. M. (2019). Brief review: Effects of isometric strength training on strength and dynamic performance. *Int J Sports Med*, *40*(6), 363-375. https://doi.org/10.1055/a-0863-4539

Macaluso, F., Isaacs, A. W., & Myburgh, K. H. (2012). Preferential type ii muscle fiber damage from plyometric exercise. *J Athl Train*, *47*(4), 414-420. https://doi.org/10.4085/1062-6050-47.4.13

Miranda, C., Rago, V., Silva, J. R., & Rebelo, A. (2021). Effects of traditional vs. Complex strength training added to regular football training on physical capacities in u19 football players: A team study. *Sport Sci Health*. https://doi.org/10.1007/s11332-021-00833-9

Powers, S. K., & Howley, E. T. (2018). *Exercise physiology: Theory and application to fitness and performance* (10th ed.). McGraw-Hill Education. accessphysiotherapy.mhmedical.com/content.aspx?aid=1154793779

Ramirez-Campillo, R., Thapa, R. K., Afonso, J., Perez-Castilla, A., Bishop, C., Byrne, P. J., & Granacher, U. (2023). Effects of plyometric jump training on the reactive strength index in healthy individuals across the lifespan: A systematic review with meta-analysis. *Sports Med*. https://doi.org/10.1007/s40279-023-01825-0

Schulz, K. F., Altman, D. G., & Moher, D. (2010). Consort 2010 statement: Updated guidelines for reporting parallel group randomised trials. *British Medical Journal*, *340*, c332. https://doi.org/10.1136/bmj.c332

Scott, D. J., Ditroilo, M., Orange, S. T., & Marshall, P. (2023). The effect of complex training on physical performance in rugby league players. *Int J Sports Physiol Perform*, *18*(3), 240-247. https://doi.org/10.1123/ijspp.2021-0565

Scott, D. J., Marshall, P., Orange, S. T., & Ditroilo, M. (2023). The effect of complex training on muscle architecture in rugby league players. *Int J Sports Physiol Perform*, *18*(3), 231-239. https://doi.org/10.1123/ijspp.2021-0570

Silva, J. R., Nassis, G. P., & Rebelo, A. (2015). Strength training in soccer with a specific focus on highly trained players. *Sports Med Open*, *1*(1), 17. https://doi.org/10.1186/s40798-015-0006-z

Stasinaki, A. N., Gloumis, G., Spengos, K., Blazevich, A. J., Zaras, N., Georgiadis, G., Karampatsos, G., & Terzis, G. (2015). Muscle strength, power, and morphologic adaptations after 6 weeks of compound vs. Complex training in healthy men. *J Strength Cond Res*, *29*(9), 2559-2569. https://doi.org/10.1519/jsc.0000000000000917

Stewart, P. F., Turner, A. N., & Miller, S. C. (2014). Reliability, factorial validity, and interrelationships of five commonly used change of direction speed tests. *Scand J Med Sci Sports*, *24*(3), 500-506. https://doi.org/10.1111/sms.12019

Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of soccer: An update. *Sports Med*, *35*(6), 501-536. https://doi.org/10.2165/00007256-200535060-00004

Stone, M. H., Hornsby, W. G., Suarez, D. G., Duca, M., & Pierce, K. C. (2022). Training specificity for athletes: Emphasis on strength-power training: A narrative review. *J Funct Morphol Kinesiol*, *7*(4). https://doi.org/10.3390/jfmk7040102

Templeton, G. F. (2011). A two-step approach for transforming continuous variables to normal: Implications and recommendations for is research. *Communications of the association for information systems*, *28*(1), 4.

Thapa, R. K., & Kumar, G. (2023). Does complex contrast training induce higher physical fitness improvement in stronger compared to weaker individuals? *Montenegrin Journal of Sports Science and Medicine*, *19*(1), 43-51. https://doi.org/10.26773/mjssm.230306

Thapa, R. K., Kumar, G., Raizada, S., & Bagchi, A. (2023). Effects of contrast training with two sessions weekly frequency on physical fitness of university-level male soccer players. *Physical Education Theory and Methodology*, *23*(6), 886-893.

Thapa, R. K., Kumar, G., Weldon, A., Moran, J., Chaabene, H., & Ramirez-Campillo, R. (2023). Effects of complex-contrast training on physical fitness in male field hockey athletes. *Biomedical Human Kinetics*, *15*(1), 201-210. https://doi.org/doi:10.2478/bhk-2023-0024

Thapa, R. K., Lum, D., Moran, J., & Ramirez-Campillo, R. (2021). Effects of complex training on sprint, jump, and change of direction ability of soccer players: A systematic review and meta-analysis. *Front Psychol*, *11*, 627869. https://doi.org/10.3389/fpsyg.2020.627869

Thapa, R. K., Narvariya, P., Weldon, A., Talukdar, K., & Ramirez-Campillo, R. (2022). Can complex contrast training interventions improve aerobic endurance, maximal strength, and repeated sprint ability in soccer players? A systematic review and meta-analysis. *Montenegrin Journal of Sports Science and Medicine*, *11*(2), 45-55. https://doi.org/10.26773/mjssm.220906

Thapa, R. K., Sarmah, B., Singh, T., Kushwah, G. S., Akyildiz, Z., & Ramirez-Campillo, R. (2023). Test-retest reliability and comparison of single-and dual-beam photocell timing system with video-based applications to measure linear and change of direction sprint times. *Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology*, 17543371231203440.

Thapa, R. K., Uysal, H., Clemente, F. M., Afonso, J., & Ramirez-Campillo, R. (2024). Effects of complex training compared to resistance training alone on physical fitness of healthy individuals: A systematic review with meta-analysis. *J Sports Sci*, *42*(14), 1367-1389. https://doi.org/10.1080/02640414.2024.2391657

Thapa, R. K., Weldon, A., Freitas, T. T., Boullosa, D., Afonso, J., Granacher, U., & Ramirez-Campillo, R. (2024). What do we know about complex-contrast training? A systematic scoping review. *Sports Med Open*, *10*(1), 104. https://doi.org/10.1186/s40798-024-00771-z

Weldon, A., Duncan, M. J., Turner, A., Sampaio, J., Noon, M., Wong, D. P., & Lai, V. W. (2021). Contemporary practices of strength and conditioning coaches in professional soccer. *Biol Sport*, *38*(3), 377-390. https://doi.org/10.5114/biolsport.2021.99328

Wild, J., Bezodis, N. E., Blagrove, R. C., & Bezodis, I. N. (2011). A biomechanical comparison of accelerative and maximum velocity sprinting: Specific strength training considerations. *Professional Strength and Conditioning*, *21*, 23-37.

Wilson, G. J., Murphy, A. J., & Giorgi, A. (1996). Weight and plyometric training: Effects on eccentric and concentric force production. *Canadian Journal of Applied Physiology*, *21*(4), 301-315.

Zehr, E. P., & Sale, D. G. (1994). Ballistic movement: Muscle activation and neuromuscular adaptation. *Can J Appl Physiol*, *19*(4), 363-378. https://doi.org/10.1139/h94-030