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Effects of Complex-Contrast Versus Traditional Resistance Training on Linear Sprint, Change-of-Direction Speed, Jumps, and Maximal Strength of Physically Active Males

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ABSTRACT

Background: Complex-contrast training (CT) combines traditional resistance training (RT) and ballistic training exercises to induce neuromuscular adaptation. However, adding ballistic exercises with RT exercise in CT format induces superior neuromuscular adaptation compared to performing RT alone, which needs investigation. **Objective:** This study compared the effects of seven-week CT and RT intervention on selected physical fitness measures among physically active adult males. **Methods:** A 2 × 2 repeated measures ANOVA design was used to analyse the effects of training intervention on physical fitness measures. Pre- and post-intervention data were collected for 30-m linear sprint time (with split times measured at every 5 m), countermovement jump (CMJ) height, triple hop distance, change-of-direction (COD) time, and one-repetition maximum (1RM) squat. **Results:** Significant within-group improvements were observed in the 1RM squat (both $p<0.001$), CMJ (CT, $p<0.001$; RT, $p=0.003$), and 10 m to 30 m linear sprint times (CT, all $p<0.001$; RT, $p=0.003$-0.011) for both the experimental groups. However, significant within-group improvements for triple-hop distance ($p<0.001$) and 5 m sprint ($p=0.008$) were observed only in the CT group. A significant deterioration in performance was observed for COD deficit (CT, $p=0.020$; RT, $p=0.019$) in both the experimental groups. A significant deterioration in COD total time was observed in the RT group (p=0037). A significant group-by-time interaction was observed only in 5 m linear sprint time ($p=0.042$), favouring the CT group. **Conclusion:** Seven weeks of CT and RT improved the 1RM squat, CMJ height, and 10 m, 15 m, 20 m, 25 m, and 30 m linear sprint times. Meanwhile, the triple-hop distance and 5 m sprint time improved only after CT. Lastly, CT improved the 5 m sprint time more effectively than RT.

Key words: Plyometric Exercise, Athletic Performance, Resistance Training, Muscle Strength, Human Physical Conditioning, Exercise

INTRODUCTION

Physical fitness variables such as linear sprints, change-of-direction speed (CODS), vertical jumps, and maximal strength can be improved using several resistance training methods (Barrio et al., 2023; Kumar, Pandey, Ramirez-Campillo, et al., 2023; Ojeda-Aravena et al., 2023; Ramirez-Campillo et al., 2022; Rathi et al., 2023; Singh et al., 2022). Two resistance-training methods commonly used by practitioners are complex training and traditional resistance training (RT) (Loturco et al., 2023; Zhong et al., 2023). The RT is a training method that encompasses participants lifting moderate to heavy weights (i.e., 60-90% of one repetition maximum [1RM]), generally using barbells and dumbbells (e.g., squats) (Santos et al., 2022). In contrast, complex training combines exercises from two distinct resistance-training methods (i.e., RT and ballistic training) within a single session (Thapa et al., 2021). The ballistic training exercise usually involves lifting the individual's own body mass (Thapa, Chaware, et al., 2024; Thapa, Sarmah, et al., 2024) or considerably lighter weights (e.g., 30%1RM) (Loturco et al., 2020). Both complex training and RT have been shown to improve the physical fitness attributes of active individuals across the population (Rathi et al., 2023; Thapa, Kumar, et al., 2023; Thapa et al., 2022).

Furthermore, although both complex training and RT improve physical fitness abilities, whether one training method is better than another requires clarification. Theoretically, the complex training method should induce superior improvements in physical fitness attributes, as the training method utilises two different exercises that target distinct portions of the force-velocity curve (i.e., RT exercise majorly targets the force component while the ballistic exercise targets the velocity component), unlike RT, which majorly targets the force component alone. Moreover, during complex training, the RT and ballistic exercises can be sequenced in different order (e.g., descending, ascending, and contrast)

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(Cormier et al., 2022). Of these sequencing formats, complex-contrast training (CT) uses RT and ballistic exercises in a set-by-set approach (Thapa & Kumar, 2023; Thapa et al., 2021; Thapa et al., 2022). An additional theoretical advantage of using such a sequencing format is the post-activation performance enhancement of the later ballistic exercise due to the RT exercise (Cormier et al., 2022).

However, as per the authors' knowledge, previous research that compared CT and RT in physically active male participants is scarce, with only one study available (MacDonald et al., 2012). The authors compared six weeks of CT and RT intervention with two weekly sessions on recreationally training college-aged men (MacDonald et al., 2012). No between-group differences (CT versus RT) in improvement in maximal strength of lower limb (i.e., 1RM back squat, standing calf raises, and Romanian deadlift) and girth measures (i.e., quadriceps, triceps surae muscle group) were observed. Furthermore, the authors did not include other physical fitness variables (e.g., linear sprint, jumps, CODS) (MacDonald et al., 2012). Moreover, other studies that compared CT and RT in athletic populations (e.g., Australian footballers, endurance runners, baseball athletes) also reported no between-group difference in improvements of physical fitness variables (e.g., 5m, 10m, 20m linear sprint times, vertical jumps, standing broad jump, CODS, maximal strength) (Dodd & Alvar, 2007; Li et al., 2021; Schneiker et al., 2023).

Due to a limited number of studies comparing CT and RT, it is evident that there is a need for more research to reach a conclusive judgment. Indeed, replication of research is a critical way to build confidence in the findings (e.g., increase or decrease confidence in claims) (Murphy et al., 2023). Therefore, this study was conducted with the aim of comparing the effects of CT and RT in improving 30 m linear sprint time (with split times measured at every 5 m distances), countermovement jump (CMJ) height, CODS time, triple-hop distance, and 1RM squat (i.e., maximal strength) in physically active males. Based on the literature and previous studies, the authors hypothesised there would be differences in the improvement of physical fitness between CT and RT.

METHODS

Participants

The minimum number of participants (i.e., sample size) required for the study was estimated by conducting *a priori* analysis using open-source software (i.e., G*power software, version 3.1.9.7). The results indicated a minimum number of 11 participants would be required to achieve statistical significance with two groups (i.e., CT & RT), two measurements (pre- and post-intervention), alpha error probability of <0.05, nonsphericity correction of 1, correlation between repeated measures = 0.7; desired power (1-ß error) = 0.80; and effect size (f) of 0.25 (medium effect size) using repeated measures ANOVA. Due to a limited number of studies that compared CT and RT for physical fitness variables of interest (i.e., linear sprints, CMJ, CODS), the authors selected a medium effect size.

Therefore, considering the possible attrition of participants in such studies, more individuals were contacted (n=49). The interested individuals were then assessed for eligibility for inclusion in the study based on the criteria that required the participants to (a) be physically active adults; (b) be injury-free in the past six months; (c) have previous resistance training experience (d) be able to perform squat, deadlift, and calf raise exercises; (e) willingness to undergo seven-week intervention and selected physical fitness assessments before and after the intervention. After that, the eligible participants were allocated randomly (using online randomisation software available at www.randomizer.org) to either the CT or RT group using an allocation ratio of 1:1. Table 1 provides the anthropometric and demographic details of the participants. The benefits and potential risks associated with the intervention were explained to the participants during the eligibility screening process. The participants then signed the informed consent forms. The study was approved by the university's institutional review board and was conducted following ethical principles established in the Helsinki Declaration guidelines. Participants were excluded from the final analysis if they attended less than 80% of the training sessions.

Experimental Design

The study was conducted using a two (within-group, pre- and post-intervention assessments) by two (between-group, CT and RT experimental groups) randomised study design to compare the effects of CT and RT on selected outcome measures. The assessments at pre- and post-intervention were carried out at comparable hours during the day to minimise the effect of circadian rhythm. In addition, the assessments were conducted after a rest period of a minimum of 48 hours from the last training session to avoid the influence of fatigue. The sequence of the tests and participants performing those tests were the same for baseline and post-intervention assessments. Due to logistical reasons, the participants' group allocation was not blinded to the researchers or assessors involved in the data collection procedures.

A one-week familiarisation session was conducted before the baseline data collection. The sessions included a typical CT session and the contrast pairs of exercises to be used

Table 1. Participant characteristics in contrast training (CT) and traditional resistance training (RT) groups

Variables	CT group (n=14)	RT group (n=8)	P-value
	Mean (Standard deviation)		
Age (years)	22.1 (1.8)	21.3 (2.1)	0.348
Height (cms)	172.4 (7.7)	172.6 (6.5)	0.952
Body Mass (kgs)	67.9 (9.4)	66.8 (9.7)	0.783
BMI	22.8 (2.5)	22.3 (2.0)	0.642
1RM back squat	109.3 (11.2)	94.4 (14.3)	0.013*

*significant difference between groups; 1RM – one repetition maximum, BMI – body mass index during the intervention. In addition, the physical fitness tests were also explained and practised by the participants during these sessions to minimise the learning effects. Furthermore, the participants' anthropometric and demographic data were also collected during these sessions. Furthermore, instructions (and time-to-time reminders) were provided to the participants to avoid (up to 48 hours before testing) any activity or exercise (i.e., strenuous) that could affect the testing results. In addition, participants were asked to eat and drink as per their daily habitual routine. However, the participants were instructed to avoid heavy eating up to 3 hours before the scheduled testing time. The detailed schematic representation of the study is provided in Figure 1.

Training Intervention

The experimental groups performed two-weekly sessions of either CT or RT for seven weeks. Between two consecutive training sessions, a minimum of 48 hours of recovery was provided. The exercises (i.e., contrast pairs) were selected based on recommendations from a previous study (Cormier et al., 2022). Four biomechanically similar RT and ballistic exercises were paired as contrast exercises, i.e., back squats with CMJs, walking lunges with split jumps, Romanian deadlifts with standing broad jumps, and standing calf raises with pogo jumps. Meanwhile, the RT group only performed back squats, walking lunges, Romanian deadlifts, and standing calf raises. The CT and RT groups performed the traditional resistance exercise with similar intensity (i.e., %1RM), while the CT group additionally performed the ballistic exercises. All training sessions started with a warm-up of ~10 minutes duration that included jogging, dynamic stretching of lower limb muscles, and warm-up sets of included exercises (i.e., squats, lunges, Roman deadlift, standing calf raises) using the empty barbell. Post-training sessions, the participants were not restricted to a standard cooling-down protocol. However, the participants were encouraged to perform their self-selected habitual protocol (e.g., stretching). Table 2 provides details on the training intensity and volume used during the intervention.

Physical Fitness Assessments

The assessments of selected physical fitness outcome variables were conducted across four days, with jump-based testing (i.e., CMJ and triple-hop test) conducted on the first day, CODS conducted on the second day, linear sprinting conducted on the third day, and 1RM assessment conducted on the fourth day. The same researcher or assistants conducted the test before and after the intervention and were not blinded to the participant's group allocation. Before each testing session, all the participants followed a 10-minute general warm-up routine. This consisted of running at a self-selected pace, followed by dynamic stretching of lower limb muscles (Thapa, Clemente, et al., 2023). Thereafter, participants performed sub-maximal bouts of activities according to the test (e.g., sub-maximal CMJs, sprints) as a specific warm-up.

Linear sprint

The 30 m linear sprint test was conducted outdoors on a natural grass turf, with split time measured at each 5 m distance. The participants were asked to stand at the start point and use a self-selected start approach for the test. The timings were measured through the video-analysis method using validated and reliable software (MySprint) (Romero-Franco et al., 2017; Thapa, Sarmah, et al., 2023). For the analysis, the video was recorded using an Apple iPad with a frequency of 120 frames per second. The Apple iPad was placed 18 m away at a fixed point perpendicular to the sprinting lane 20 m from the start. A detailed description of the testing protocol is available elsewhere (Romero-Franco et al., 2017). Two trials with an inter-trial recovery of 3 minutes were conducted.

Countermovement jump

The CMJ tests were conducted to assess the lower limb muscle's stretch-shortening cycle function. The participants were instructed to jump with a self-selected countermovement depth and their hands placed on the hips. In addition, partici-

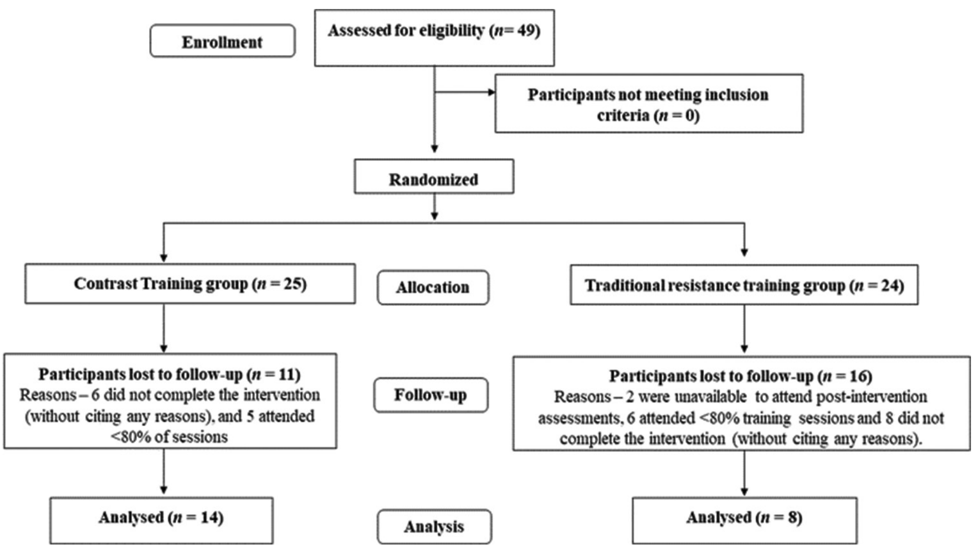

Figure 1. Schematic representation of the study using the CONSORT flow diagram

Table 2. Description of training intensity and volume for both the intervention groups

Week	Training day 1			Training Day 2		
	Resistance exercise		Ballistic Exercise	Resistance exercise		Ballistic Exercise
	% 1RM	Set×Repetitions	Set×Repetitions	% 1RM	Set×Repetitions	Set×Repetitions
1	70	3×7	3 ×8	70	3 ×6	3×8
2	75	3×7	3 ×8	75	3×5	3 ×8
3	78	3×6	3 ×10	78	3×5	3 ×10
4	80	3 ×6	3 ×10	80	3 ×5	3 ×10
5	82	3 ×5	3 ×12	82	3×5	3 ×12
6	85	3 ×4	3 ×12	85	3×4	3 ×12
7	88	4 ×3	4 ×10	88	3×3	4 ×10

The traditional resistance exercise group performed the resistance exercise alone with the same load and repetition. The complex-contrast training group performed additional ballistic exercises

pants were provided specific instructions on how to perform the jumps to achieve maximum height without flexing their knees or moving their hands from the hips. The jumps were recorded using the slow motion feature (i.e., 120 frames per second) of an Apple iPad 8th generation (Apple Inc., California, USA) with the camera as low as possible (to capture the ground release or contact accurately), with participants performing the jumps in the frontal plane. The recorded videos were then used to calculate the jump height using a validated and reliable software (MyJump) (Gallardo-Fuentes et al., 2016). Each participant performed three jump trials with an inter-jump recovery duration of 3 minutes, and the best trial was selected for further analysis.

Triple-hop test

The triple-hop test was conducted outdoors on a natural grass turf with measuring tape attached to the ground. The test protocol is available elsewhere (Wood, 2008). Three trials were performed with an inter-trial recovery duration of 3 minutes. The best trial (i.e., the furthest distance) was selected for further analysis.

Change of direction speed

The CODS was assessed using the traditional 5-0-5 test conducted on a natural grass field. The participants sprinted 15-m toward a marked line and performed a 180-degree turn (from the marked line) toward the starting line. The video of the trials was recorded with the slow motion feature (i.e., 120 frames per second) of an Apple iPad 8th generation (Apple Inc., California, USA) with the camera placed at a 5 m distance from the starting line. A reliable video-based application (COD timer) (Thapa, Sarmah, et al., 2023) was used to measure the total time, COD deficit, and contact time during the 5-0-5 test from the recorded videos. Furthermore, the participants were allowed to self-select the leg to change direction. Due to logistical reasons, the test was not conducted on the other leg. The participant's testing leg was similar at both pre- and post-intervention assessments. Three COD trials were performed with an inter-trial recovery duration of 3 minutes.

Maximal strength

The maximal strength of the participants was assessed using the 1RM squat test conducted on a Smith machine. Each participant performed sub-maximal lifts after the general warm-up procedure, allowing them to perform 8-10 repetitions. After that, based on the previous experience, the participants selected a weight that would allow three repetitions. The weights were progressively increased through incremental sets, with 3-5 minutes of rest between attempts. The test continued until the participants could no longer complete one full squat with proper form.

Statistical Analysis

Before applying the parametric tests, the data were assessed for normal distribution using the Shapiro-Wilk tests. A two-step transformation was applied in case the data was not normally distributed, as suggested in a previous study (Templeton, 2011). The normally distributed data are presented as mean and standard deviation. Whilst, the non-normally distributed data are presented as median and interquartile range. A two-by-two repeated measures ANOVA with pre- and post-intervention data as within-group factors and intervention (i.e., CT versus RT) as between-group factors were used to analyse the effects of training on the dependent variables. In addition, post-hoc analyses using Bonferroni-adjusted t-tests were conducted to analyse the within-group (i.e., paired t-tests) and between-group (i.e., independent t-tests) comparisons. Furthermore, effect sizes for each variable were calculated for interaction and main effects using partial eta squared (ηp2). To assess changes between baseline (i.e., pre-intervention) and follow-up (i.e., post-intervention) testing, Hedge's g effect sizes were calculated. For ηp2, <0.06 was interpreted as small, ≥0.06-0.13 was interpreted as a medium, and ≥0.14 was interpreted as a large magnitude of effects (Cohen, 1988). For Hedge's g, <0.2 was interpreted as trivial, 0.2-0.6 was interpreted as small, (>0.6-1.2 was interpreted as moderate, (>1.2-2.0 was interpreted as large, and >2.0-4.0 was interpreted as very large (Hopkins et al., 2009). In addition, percentage change scores were calculated using Microsoft Excel for each dependent variable for each intervention group with the equation:

$[(\text{mean}_{post} - \text{mean}_{pre})/\text{mean}_{pre}] \times 100$. The statistical software SPSS (version 24.0.0; IBM, New York, USA) was used for all the analyses unless stated otherwise. The statistical significance was set at $p \leq 0.05$.

RESULTS

Participant's Characteristics

Table 1 provides data on the participant's anthropometric and demographic characteristics. No significant differences were noted between CT and RT participants in age, body mass, and height. However, the 1RM back squat significantly differed among participants between experimental groups. This may have been possible due to the significant attrition of participants from the study (the data represents the final analysed participants).

Within-group Analysis

A significant main effect of time (with positive improvements in performance) was observed in 1RM strength, triple hop distance, CMJ height, 10 m, 15 m, 20 m, 25 m, and 30 m linear sprint times. In contrast, a significant main effect of time (with deterioration in performance) was observed for COD's total time and COD's deficit. No main effect of time was observed in COD contact time.

Furthermore, significant within-group improvements were observed in the 1RM squat, triple hop distance, CMJ, and 5 m, 10m, 15 m, 20 m, 25 m, and 30 m linear sprint times for the CT group. Similarly, significant within-group improvements were also observed in 1RM squat, CMJ, and 10 m, 15 m, 20 m, 25 m, and 30 m linear sprint times for the RT group. In addition, a significant deterioration in performance was observed for COD deficit in both the experimental groups, and a significant deterioration in COD total time was observed in the RT group, but no changes were observed in the CT group. Lastly, the COD contact time remained unchanged after the intervention for both experimental groups. The pre- to post-intervention percentage change is graphically presented in Figure 2.

Time × Group Interaction

A significant time × group interaction effect was observed in 5 m linear sprint time (large ES), favouring the CT group. In addition, no significant time × group interaction effect was observed in any other dependent variables. The results of the statistical analyses are presented in Table 3.

DISCUSSION

This study aimed to compare the effects of CT and RT in improving linear sprint time (with 5 m, 10 m, 15 m, 20 m, 25 m, and 30 m split times), CMJ height, CODS time, and 1RM squat (i.e., maximal strength) in physically active males. The findings indicated a significant improvement from pre- to post-intervention in 10 m, 15 m, 20 m, 25 m, and 30 m linear sprint times, 1RM squat, triple-hop distance, and CMJ height for both the experimental training groups. However, the 5 m linear sprint time and triple-hop distance improved only in the CT group but not in the RT group. Furthermore, the total time in COD significantly deteriorated in the RT group, but no changes were observed in the CT group. The COD deficit deteriorated in both experimental groups, and no changes were observed in the COD contact time. A significant group × time interaction was observed only in the 5 m linear sprint time, favouring the CT group.

The improvements through CT may be attributed to adaptations that support the muscle's force-generation capabilities by improving the stretch-shortening cycle muscle function and intra-and-inter-muscular coordination, increasing the motor unit recruitment and firing frequency, and inducing positive morphological and structural changes (Cormier et al., 2022). Moreover, previous CT studies have also reported significant improvements in linear sprint time, CMJ height, and 1RM squat after CT intervention (Kumar, Pandey, Ramirez-Campillo, et al., 2023; Kumar, Pandey, Thapa, et al., 2023; Thapa & Kumar, 2023; Thapa, Kumar, et al., 2023; Thapa et al., 2021; Thapa et al., 2022). Moreover, a meta-analysis by Thapa et al. (2021) reported significant improvement in linear sprint times (i.e., 5 m, 10 m, 15 m, 20 m, and 30 m) and CMJ height after CT. In addition, another meta-analysis reported significant improvement in the maximal strength (i.e., 1RM) of the lower limb after CT (Thapa et al., 2022). Furthermore, the significant improvement in 10 m, 15 m, 20 m, 25 m, and 30 m linear sprint times and CMJ height after RT may be attributed to improved muscle recruitment and activation, resulting in an improved rate of force development. Another possible reason for the improvements in linear sprints and CMJ in both experimental (i.e., RT and CT) groups may be the increase in the maximal strength (i.e., 1RM squat) of the lower limb, possibly resulting in a transference effect. A previous study reported lower limb maximal strength associated with linear sprint and vertical jump among elite soccer players (Wisløff et al., 2004).

In addition, a significant improvement was observed in the triple-hop distance and 5-m linear sprint time after CT but not with the RT. Furthermore, a group × time interaction was observed for the 5-m linear sprint time, favouring the CT group. One possible reason for these findings is the inclusion of ballistic exercises (i.e., plyometric jumps) in the CT. A previous study has reported that performing only heavy RT exercises reduces type IIx muscle fibres (Adams et al., 1993), while another recent study reported that CT preserves the type IIx muscle fibres (Stasinaki et al., 2015), possibly due to the inclusion of the ballistic exercise (Grgic et al., 2021; Macaluso et al., 2014; Macaluso et al., 2012). Furthermore, the CT intervention may also have favoured effective energy transfer between the eccentric and concentric muscle action (due to the inclusion of ballistic exercises), thus providing better inter-muscular coordination and synchronisation of active muscle groups to improve and enhance motor skills (i.e., 5-m linear sprinting) (Cronin et al., 2001). In addition, ballistic training, such as plyometric jumps training, has also been shown to improve the reactive strength index of healthy

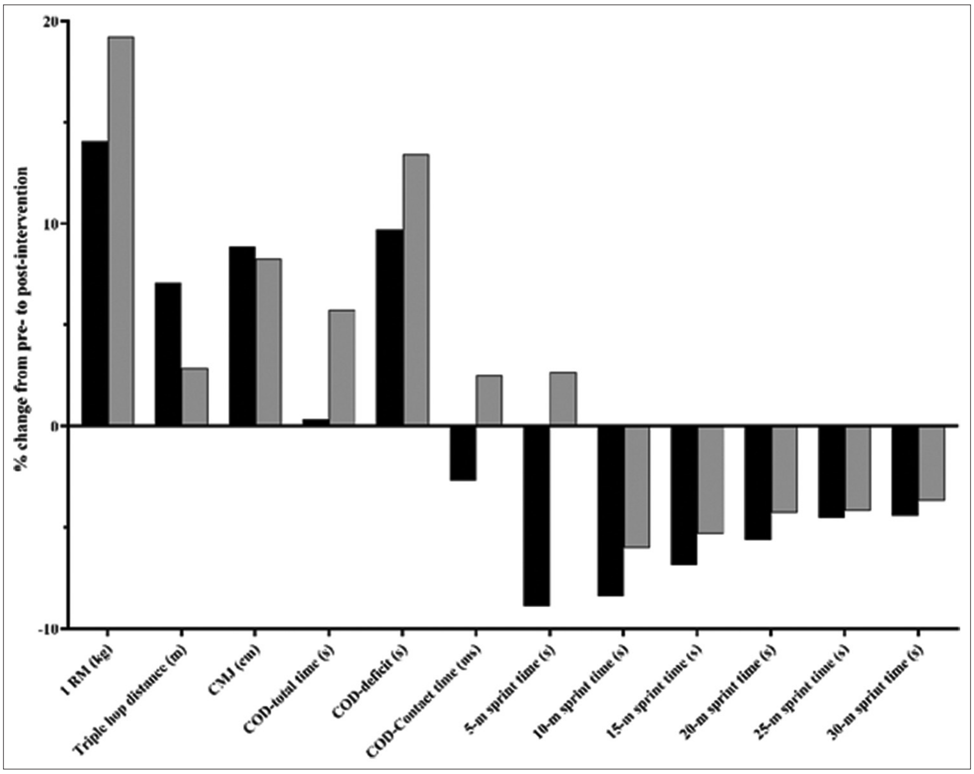

Figure 2. Percentage change (relative) in dependent variables between pre- and post-intervention assessments for complex-contrast training (black bars) and traditional resistance training (grey bars)
1 RM – one repetition maximum in squat, CMJ – countermovement jump, COD – change of direction.

individuals (Ramirez-Campillo et al., 2023), which may be another possible reason for improved 5-m linear sprint time and triple-hop distance.

Furthermore, for the COD tests, a significant deterioration was observed in the COD deficit for both groups, with no changes in the COD contact time after intervention. However, the CT group maintained the total time during the COD assessment, while the RT showed negative results post-intervention. These findings are similar to previous studies conducted on soccer players that reported no improvement in COD performance after CT or RT (Alves et al., 2010; Cavaco et al., 2014; Faude et al., 2013). A partial explanation for these findings is that COD movements depend more on motor control factors than maximal strength or ability to apply strength speed (Young et al., 2001). The current study incorporated no COD exercises or drills into the training intervention. Indeed, the participants involved in the current study were only physically active and were not undergoing any sport-specific training regime, which may also explain why some CT studies conducted on participants practising sports with high COD demands (e.g., soccer) improve the COD performance (Thapa et al., 2021).

Of note, no significant group × time interactions were reported for 1RM squat, triple-hop distance, COD variables, and 10-m, 15-m, 20-m, 25-m, and 30-m linear sprint times. Previous studies that compared CT and RT reported similar findings (Dodd & Alvar, 2007; Li et al., 2021; MacDonald et al., 2012; Schneiker et al., 2023). The reason for the lack of improvement may be due to the similarity in the adaptations of both training methods. In addition, the participants included in the current study were physically active participants who possibly were in a phase of 'window of opportunity' for adaptations to any training program.

Lastly, a few limitations in the current study should be acknowledged. Firstly, the study involved physically active male participants. Therefore, the findings from this study should not be extrapolated to females or participants who practice sports. Future studies should verify if similar findings are observed for the athletic population. Secondly, although a larger number of participants were recruited after the sample size determination (n = 49), an approximately 50 % attrition rate (n = 27) was observed in the study. Most participants stated time commitments as the reason for dropping out of the study. No participants dropped out of the study due to injury sustained during the intervention. Thirdly, the study did not include a control group. The inclusion of an additional control group would allow the comparison of improvements against a control condition. Lastly, including biochemical markers (e.g., creatine kinase for muscle damage) would provide a better insight into how the body acutely responds to these interventions.

Practical Implications

Improvement of maximal strength, vertical jump, or linear sprint (10-m to 30-m distances) may be achieved using CT or RT. The intensity of 70% to 88% 1RM squat may be used to program the training intervention. However, CT may be a preferred option if the goal is to improve the short sprint of

Table 3. Statistical comparison results of complex-contrast and traditional resistance training

Complex-Contrast Training (*n*=14)						
Variable	**Pre-test**		**Post-test**		**P-value ES (g)**	**Main time effect p-value [ηp2]**
	Mean	**SD**	**Mean**	**SD**		
1 RM squat (kg)	109.3	11.2	124.6	13.67	<0.001[M]	<.001 [.78]
Triple hop distance (m)	7.0	0.5	7.5	0.71	<0.001[M]	.001 [.42]
CMJ height (cm)	39.3	6.7	42.8	7.22	<0.001[S]	<.001 [.62]
COD total time (s)	2.73	0.16	2.74	0.19	0.858[T]	.074 [.15]
COD deficit (s)	1.17	0.13	1.28	0.16	0.020[M]	.002 [.39]
Contact time (ms)	533.4	129.9	519.0	67.7	0.674[T]	.967 [.00]
5-m sprint time (s)	1.32	0.10	1.21	0.10	0.008[M]	.239 [.07]
10-m sprint time (s)	2.20	0.10	2.02	0.09	<0.001[L]	<.001 [.615]
15-m sprint time (s)	2.90	0.13	2.71	0.11	<0.001[L]	<.001 [.64]
20-m sprint time (s)	3.58	0.15	3.38	0.11	<0.001[L]	<.001 [.68]
25-m sprint time (s)	4.22	0.17	4.03	0.14	<0.001[M]	<.001 [.593]
30-m sprint time (s)	4.90	0.18	4.69	0.17	<0.001[M]	<.001 [.61]
Traditional Resistance Training (*n*=8)						**Time×Group p-value [ηp2]**
Variable	**Pre-test**		**Post-test**		**P-value ES (g)**	
	Mean	**SD**	**Mean**	**SD**		
1 RM squat (kg)	94.4	14.3	112.5	20.0	<0.001[M]	.813 [.003]
Triple hop distance (m)	7.0	0.5	7.2	0.6	0.183[S]	.117 [.12]
CMJ height (cm)	39.8	6.3	43.1	4.1	0.003[S]	.867 [.001]
COD total time (s)	2.64	0.17	2.79	0.24	0.037[M]	.111 [.12]
COD deficit (s)	1.14	0.11	1.29	0.18	0.019[M]	.609 [.01]
Contact time (ms)	478.9	85.8	490.9	90.9	0.790[T]	.642 [.01]
5-m sprint time (s)	1.25	0.05	1.29	0.12	0.564[S]	.042 [.20]
10-m sprint time (s)	2.20	0.12	2.07	0.15	0.011[M]	.376 [.04]
15-m sprint time (s)	2.91	0.16	2.76	0.15	0.009[M]	.368 [.045]
20-m sprint time (s)	3.59	0.21	3.44	0.17	0.003[M]	.415 [.035]
25-m sprint time (s)	4.26	0.25	4.08	0.19	0.006[M]	.858 [.002]
30-m sprint time (s)	4.93	0.27	4.74	0.22	0.007[M]	.625 [.013]

Data presented in italics are median and interquartile range, 1RM – one repetition maximum, CMJ – countermovement jump, COD – change of direction, ES – effect size, g – Hedges' g, ηp2 – partial eta squared, L – large, M – moderate, S – small, T – trivial.

5 m. In addition, CT may be a preferred training option if the goal is to maintain COD performance.

CONCLUSION

In conclusion, the results suggest that seven weeks of CT and RT intervention are equally effective in improving 1RM squat, CMJ, and 10 m, 15 m, 20 m, 25m, and 30 m linear sprint times. Furthermore, the CT intervention is superior in improving the 5 m linear sprint time compared to RT. In addition, a deterioration was reported in the COD deficit, with no changes in COD contact time after intervention for either group. However, CT could maintain the COD total time compared to RT, which showed a deterioration in performance.

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AUTHOR CONTRIBUTION

J.B.: conceptualisation, study design, protocol and data collection. S.S.A: conceptualisation, study design, protocol and data collection. R.K.T: conceptualisation, study design, protocol, data analysis, writing original draft, editing.

DATA AVAILABILITY

The datasets used and/or analysed during the current study are available from the corresponding author upon reasonable request.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The research ethics committee of Bharati Vidyapeeth (Deemed to be University) approved this study (Approval ID: BVDU/Ph.D./2020-2021/3779-9). The details of the study were explained to all the participants before study recruitment. A written Informed consent was obtained from all the participants. The procedures of the study were conducted according to the Declaration of Helsinki.

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