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Research article

Effects of Cluster vs. Traditional Sets Complex Training on Physical Performance Adaptations of Trained Male Volleyball Players

Bo Rong [1] and Chen Xiu [2]✉
[1] Central South University of Forestry and Technology, Changsha, Hunan, China
[2] School of Athletic Performance, Shanghai University of Sport, Shanghai, China

Abstract

This study aimed to examine the impact of different set configurations during combination of resistance and plyometric training (complex [COX]) on jumping ability, power output, strength, and hormonal adaptations in young male volleyball players after a 6-week training period. A randomized controlled trial was conducted with twenty-four trained male volleyball players under the age of 19, who were assigned to one of two groups for lower-body COX training: cluster sets (CS-COX: n = 8) or traditional sets (TS-COX: n = 8), with an additional active control group (CON: n = 8). The players underwent evaluations for countermovement vertical jump (CMVJ), spike jump (SPJ), T-test change of direction speed (T-test CODS), one repetition maximum (1RM) in the back squat and leg press, and the Wingate Anaerobic Test before and after the 6-week training intervention (12 sessions in total). Blood samples were also collected before and after training to assess resting testosterone and cortisol responses. Following the training, both the CS-COX and TS-COX groups exhibited significantly greater ($p = 0.001$) changes than the CON group in the variables, while similar improvements in maximal strength, mean power output, and testosterone adaptations were observed following the training ($p < 0.05$). Moreover, the CS-COX group demonstrated greater improvements in CMVJ (effect size [ES] = 0.36), SPJ (ES = 0.06), T-test CODS (ES = -0.60), and peak power output (ES = 0.72), along with greater reductions in resting cortisol (ES = -0.30) levels compared to the TS-COX group after the 6-week intervention ($p < 0.05$). In conclusion, the results indicate that incorporating cluster sets during COX training sessions led to more favorable changes in bio-motor ability, peak power output, and cortisol adaptations, with greater consistency and uniformity in adaptations among the players compared to traditional set configurations.

Key words: Resistance training, plyometric training, explosive power, cluster sets.

Introduction

In a volleyball match, players engage in more than 150 jumps, and it has been suggested that lower-body maximal strength and power are essential determinants that notably influence the performance of volleyball players during the match, especially for executing vigorous movements in both vertical and horizontal directions (Sheppard et al., 2008; Silva et al., 2019). A variety of training strategies can be utilized to enhance the lower-body physical components of volleyball players, including resistance training (Kitamura et al., 2020), plyometric training (Silva et al., 2019), and short sprint interval training (Tao et al., 2024). Furthermore, athletes may gain advantages from utilizing a combination of two training techniques which known as complex training wherein heavy resistance exercises combined with similar explosive or plyometric movements (Berriel et al., 2022). In fact, in a training session, experts in strength and power have integrated both resistance and plyometric training to maximize adaptations in players' power and strength performance (Watts et al., 2012; Berriel et al., 2022), as well as physiological and neuromuscular adaptations including enhancing the recruitment of motor units, and the central input to a motor unit, by increasing the phosphorylation of the myosin light chain within the muscle fiber allowing myofilaments to exhibit greater sensitivity to calcium leading to a reduction in presynaptic inhibition (Rebelo et al., 2023). Consequently, it has been thoroughly suggested that the combination of resistance training and plyometric exercises yields a superior enhancement in muscular performance than any singular training approach (Ebben, 2002; Arazi et al., 2014; Freitas et al., 2017).

Collectively, complex training (COX) is generally recognized as an effective training method for enhancing the adaptive responses in jumping ability, strength, and sprinting speed among male and female athletes (Ebben, 2002; Watts et al., 2012; Freitas et al., 2017; Berriel et al., 2022). In this training method, the incorporation of both resistance and plyometric exercises in a single session has been found to promote the development of neuromuscular environments (Rebelo et al., 2023). These mechanisms activate motor unit excitability and elevate phosphorylation of the myosin light chain, resulting in increased sensitivity of myofilaments to calcium (Rebelo et al., 2023; Ebben, 2002). The mechanisms described can establish suitable conditions for post-activation potential (PAP), resulting in more significant adaptive changes compared to standalone training methods (Ishak et al., 2021). Therefore, in volleyball athletes who need maximal performance in jumping ability and strength (Sheppard et al., 2008), the COX strategy is regarded as a viable option due to its alignment with the players' necessity for maximum physiological and neuromuscular advantages, coupled with maximizing physical performance. It seems that the COX method is an appropriate training regimen for promoting these adaptations leading to more advancement in physical performance of volleyball players (Rebelo et al., 2023; Berriel et al., 2022). A previous study conducted by Watts and colleagues (2012) demonstrated that four weeks of COX training-induced more adaptive changes in the power performance of elite junior volleyball players.

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Engaging in the conventional method of COX training usually demands a significant amount of motivation and has the potential to cause feelings of nausea and discomfort as a result of the intense physical effort required (Ishak et al., 2021). This may reduce physical tolerability among young athletes (i.e., U19 age), leading to varying relative workloads (Ebben, 2002). In addition, previous research has concluded that a heavy load during COX training could induce muscular fatigue (Kilduff et al., 2007; Ishak et al., 2021) and may induce non-uniform adaptations among team members. Incorporating brief rest periods within a set (i.e., cluster set configuration or inter-repetition rest) can aid in rejuvenating the metabolic and excitatory cellular environment, as well as lowering catabolic hormones, ultimately enhancing fatigue control during workout sessions (Davies et al., 2021).

In order to effectively address fatigue and promote the restoration of the metabolites during COX training (Ishak et al., 2021), the implementation of a cluster set has been suggested for individual resistance training (Arazi et al., 2018) and plyometric workouts (Asadi and Ramírez-Campillo, 2016) with aiming to optimize power production. In fact, it appears that engaging in cluster sets of plyometric or resistance training has been reported as an effective training strategy for optimizing performance adaptations (Arazi et al., 2018; Asadi and Ramírez-Campillo et al., 2016). In contrast to the traditional distribution of rest intervals, a cluster distribution typically involves a greater number of shorter rest periods interspersed between repetitions or groups of repetitions (sets), while maintaining a similar overall duration for the training session (Arazi et al., 2018). Consequently, a cluster set configuration permits a reduced number of repetitions per set, thereby facilitating greater muscle power generation with each repetition that could play an important role in producing higher power output during training interventions in conjunction with greater metabolic recovery leading to more advancements in training programs (Haff et al., 2008).

Although the positive impact of short-term COX training (i.e., 4 weeks) on the power performance of volleyball players has been demonstrated (Watts et al., 2012; Berriel et al., 2022), there is a lack of research on the effects of more duration of training program especially (i.e., 6 weeks) cluster sets of COX training in comparison to traditional sets for optimizing performance adaptations in volleyball players. Based on the limited research conducted on cluster sets for COX training, it appears that they can be a beneficial training tool for improving muscular strength and explosive power (Jusoh et al., 2019). Although the initial research (Ishak et al., 2021; Jusoh et al., 2019) related to cluster sets shows promise, further studies are necessary to fully understand the role of cluster sets in COX training programs. Specifically, research that incorporates cluster sets into the resistance training and plyometric training routines of athletes, such as volleyball players, is needed. In addition, determining the most suitable rest distribution - either cluster or traditional- within COX training could prove to be crucial for strength and conditioning coaches in volleyball. This selection could lead to optimal adaptations in strength, power performance, and hormonal responses, ultimately enhancing the athletes' performance during matches (Arazi et al., 2018). Therefore, the main objective of this study was to investigate the impact of a 6-week lower-body COX training with different set configurations (cluster sets vs. traditional sets) on jumping ability, power output, strength, and hormonal adaptations in young male volleyball players. Our hypothesis was that cluster sets would lead to greater improvements in muscular strength and power as well as better hormonal adaptations compared to traditional sets (Asadi and Ramírez-Campillo, 2016; Arazi et al., 2018).

Methods

Experimental design

The current study is being conducted on highly-trained (i.e., tier 3, McKay et al., 2022) U19 male volleyball players, involving a macrocycle in a specific phase (i.e., preseason) using a randomized parallel design (i.e., 1-week pre-test, 6 weeks training intervention and 1-week post-test). The randomization process was conducted using a random number generator (i.e., simple randomization) on a computer in a 1:1:1 ratio to either the cluster sets, traditional sets or control groups, leading to group assignments that were unpredictable and based on chance. This method was implemented in accordance with the guidelines outlined in the "CONSORT" statement, available at http://www.consort-statement.org. All players underwent a familiarization session in the first week (i.e., Monday), which included testing and training procedures. During this session, the players standing height (wall-stadiometer, ±0.1 cm, SECA, USA) and body mass (electrical scale, ±0.5 kg, TANITA, Japan) were assessed. 48 hours after the familiarization session (i.e., Wednesday), the players performed a series of field-based physical performance tests including countermovement vertical jump (CMVJ), spike jump (SPJ), T-test change of direction speed (T-test CODS) and one repetition maximum (1RM) of leg press with a 10-minute rest interval to ensure recovery, respectively. On Friday, the players were recruited to complete the Wingate Anaerobic Power Test to assess lower-body peak and mean power output. Following the 10-minute recovery, the 1RM in back squat exercise was measured as well. After completing testing sessions for all players, they participated in training interventions on two non-consecutive days (i.e., Tuesday, and Thursday) in addition to their regular volleyball training schedule. Prior to the initiation of the training period and following the training intervention, blood samples were collected in the morning (i.e., 9 to 10 AM) to determine the hormonal changes in the players. After the completion of the 12-session COX training period, post-tests were administered in the same manner as the pre-test assessments. In order to minimize the potential influence of circadian rhythms on the findings, all training and physical testing sessions were conducted during the afternoon hours, specifically between 4 PM and 7 PM. In this study, it was required that all subjects complete every testing session, which were monitored by a trained researcher and a specialist in strength and conditioning to confirm that all exercise tests were conducted correctly.

Participants

The initial sample size was established based on an effect size of 0.80, taking into account the partial eta squared value of 0.21 from a study that investigated the effects of COX training on the vertical jump performance of volleyball players (Berriel et al., 2022). With a target power of 0.95 and a significance level of 0.05 for F tests, specifically mixed ANOVA (between-within factors), the G*power software (version 3.1.9., Universität Düsseldorf, Germany) indicated that a total sample size of 24 was necessary. Following the determination of the required sample size, the recruitment process commenced with direct outreach to volleyball teams, involving discussions with directors and coaches. As a results, twenty-four male volleyball players under the age of 19 (18.4 ± 0.4), with a minimum of 2 years of experience in national competitions and belonging to their province team, agreed to participate in the study. All players had similar weekly training loads before their inclusion in the study (Table 1). Regarding the number of volleyball players in each team and following the previous research in the field of volleyball, a total of eight volleyball players per training group (i.e., 1 setter, 2 middle blockers, 3 outside hitters, and 2 opposite hitters) would be sufficient (Tao et al., 2024) (Figure 1). After careful screening, the players were matched based on their playing position and were randomly divided into three groups as follows: cluster sets COX training (CS-COX, n = 8, age = 18.3 ± 0.4 years, height = 182.6 ± 7.5 cm, body mass = 78.5 ± 6.2 kg, and training age = 7.1 ± 0.9 years), traditional sets COX training (TS-COX, n = 8, age = 18.5 ± 0.4 years, height = 183.1 ± 6.4 cm, body mass = 77.4 ± 5.1 kg, and training age = 7.3 ± 0.6 years) and control group (CON, n = 8, age = 18.4 ± 0.6 years, height = 181.9 ± 5.3 cm, body mass = 79.1 ± 7.2 kg, and training age = 7.6 ± 1.1 years). To be eligible, the volleyball players had to meet certain criteria. Firstly, they needed to have a background of more than 6 years of systematic volleyball training and a minimum of 3 years of competition experience. Secondly, they had to have engaged in continuous volleyball training in the past 2 years. Thirdly, they should not have had any plyometric and resistance training experience in the past 6 months. Lastly, they were required to be free from any lower body injuries that could inhibit their participation in the intervention. The study was approved by the Institutional Review Board of Central South University of Forestry and Technology, and all participants (as well as their parents or guardians) were thoroughly briefed on the experimental procedures, potential risks, and benefits related to their involvement. Prior to conducting any tests, a legally required signed informed consent/assent form was obtained.

Table 1. An overview the training program during the pre-season period.

Week days	Intervention	
	Morning session (9-11 AM)	**Evening session (4-7PM)**
Monday	Video for technical and tactical review	Volleyball technical and tactical training*, small sided games
Tuesday	Rest	COX training
Wednesday	Video for technical and tactical review	Volleyball technical and tactical training, stimulated competitive games
Thursday	Rest	COX training
Friday	Video for technical and tactical review	Volleyball technical and tactical training
Saturday	Rest	Preparation match
Sunday	Rest	Rest

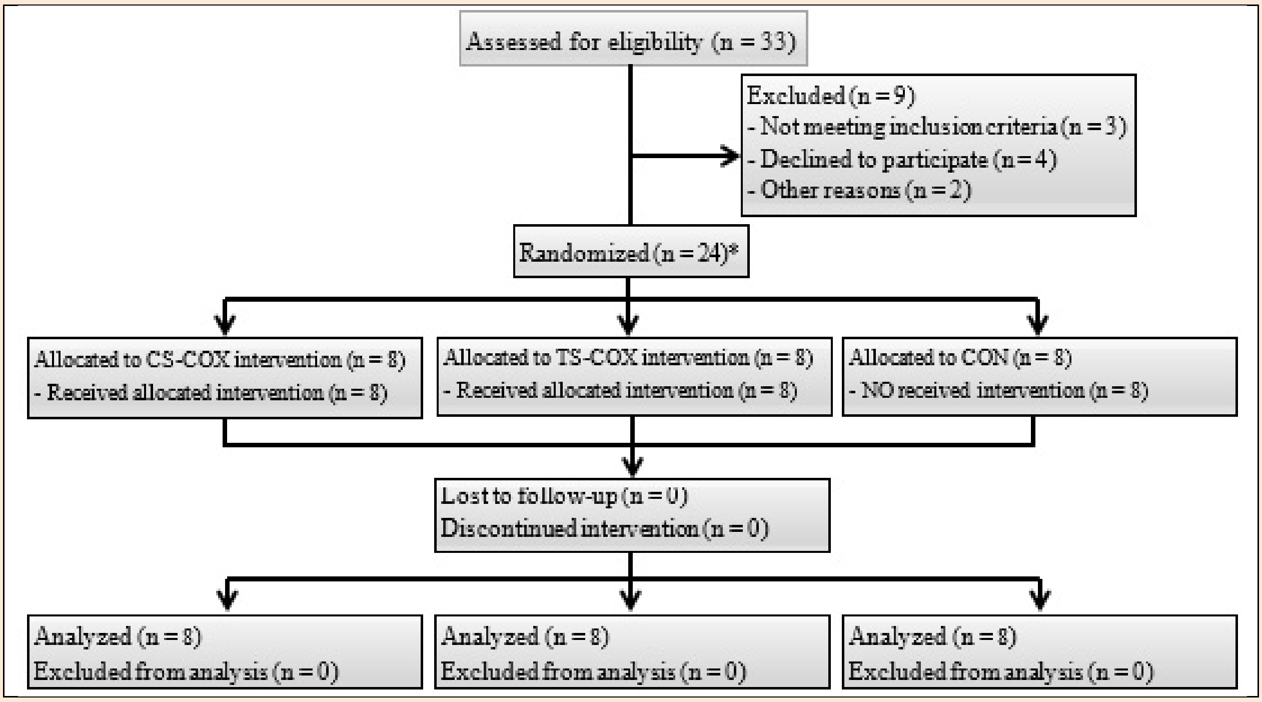

Figure 1. Study flow. *: 24 players included 3 setters, 6 middle blockers, 9 outside hitters, and 6 opposite hitters that randomly divided into 3 groups. CS-COX: cluster sets complex, TS-COX: traditional sets complex, CON: control.

Procedures

Prior to the testing day, all participants received detailed instructions. These included: 1) ensuring a sleep duration of no less than 9 hours, 2) following a specific carbohydrate intake along with adequate hydration, and 3) refraining from the use of any drugs or performance-enhancing supplements. A 15-minute general warm-up was conducted for all participants prior to the commencement of the tests. The performance evaluations were held on a wooden volleyball court, with temperatures maintained between 25 - 27°C. Additionally, hormonal measurements were taken in a laboratory environment, where temperatures ranged from 25 - 27°C and humidity levels were between 45 - 50%. A 10-minute rest interval was provided between physical performance tests to ensure full recovery in these orders: Day 1 (Wednesday), CMVJ, SPJ, T-test CODS and 1RM of leg press: Day 2 (Friday), Wingate Anaerobic Power Test and 1RM of back squat, respectively. To control for any potential effects of footwear, all participants were instructed to wear the same type of shoes during both the pre- and post-tests. It was essential for all participants to complete every testing session, which was monitored by a trained researcher and a specialist in strength and conditioning to verify the proper execution of all exercise tests.

Jumping ability

A wall-mounted jump tester (VERTEC Power System, USA) was utilized on the volleyball court to measure the CMVJ and SPJ. In order to assess CMVJ, the participants were directed to perform vertical jumps with maximum effort, to determine their jump height in centimeters. This involved executing a countermovement knee flexion until reaching a 90° angle which marked with elastic band while refraining from using their arms. The examination commenced with the participants standing, followed by knee flexion and then jumping as high as they could possibly achieve (Gjinovci et al., 2017). The reliability coefficient (ICC) for repeated measurements at CMVJ was 0.95. The SPJ began with the assessment of the participant's standing reach height using the VERTEC device mentioned earlier. Subsequently, the participant was instructed to position themselves on the floor, maintaining a distance of 3-4 m from the VERTEC device. Upon receiving the investigator's command, the participants initiated an approach run toward the VERTEC device and executed a complete spiking action using the palm of their spiking hand. A standard run-up for a volleyball spike, involving four-step approaches, was permitted. The score for the SPJ was recorded by subtracting the jumping height from the participant's standing reach height in centimeters (Dell'Antonio et al., 2022). The ICC for repeated measurements at SPJ was 0.93. Each test was performed three times and the best score was selected for further analysis. Each participant performed 3 maximal jumps for each test, with a 30-sec rest period between each attempt. The coefficient of variation (CV) of the CMVJ and SPJ were 2.24 % and 3.13 %, respectively.

T-test change of direction speed

The T-test CODS was used to assess changes in direction speed (both right and left sides), forward sprinting, and back-pedaling for the volleyball players. This test involved placing three cones 5 m apart in a straight line, with a fourth cone positioned 10 m away from the middle cone to create a T shape. The participants were directed to initiate a sprint from a stationary position towards a cone located 10 m away. Subsequently, they were to perform a side-shuffle to the left, reaching a cone positioned 5 m away. Upon touching this cone, the participants then side-shuffled to the cone situated 10 m to the right, before returning to the central cone through another side-shuffle. The assessment was finalized with a back-pedal to the original starting line. The test was conducted on the volleyball wooden court within an indoor facility. Participants completed two maximal trials, separated by a two-minute rest period and the best time (±0.0015 sec, Cronox 3.0, Photocell Timing System, Spain) from the two trials was chosen for further analysis based on the best leg (Miller et al., 2006). The ICC for repeated measurements was found to be 0.96, while the CV for the T-test CODS was recorded at 4.16%.

Maximal strength

Lower body maximal strength was measured by 1RM of leg press (45° knee flexion, POWERTEC leg press device, USA), and back squat (90° knee flexion, A983 Smith Machine, Sports Art Fitness, USA) exercises. The 1RM assessment was conducted following the protocols established by Kraemer and Fry (1995). The testing process involved the following steps: first, after a general warm-up, each participant completed a set of 5 repetitions with light loads (approximately 50% of their estimated 1RM). Subsequently, they executed 3 - 4 repetitions with heavier loads (approximately 75% of their estimated 1RM). From this point, the participants carried out a single repetition with every subsequent augmentation in load until they reached the state of volitional failure or incomplete correct range of motion. Each set was separated by a two-minute break to provide rest. The participants were verbally encouraged to exert their full potential during the test. Throughout the testing sessions, spotters were in place to ensure safety.

Wingate anaerobic power test

Following a 10-minute warm-up on the bicycle, the assessment of the lower body's peak power (highest power achieved at the 5-sec mark) and mean power output (average power output throughout the entire test) were measured using a 30-sec maximal Wingate test. This test involved the use of a mechanically braked cycle ergometer (model 894E, Monark, Sweden) with the resistance adjusted to 0.075 $kg.kg^{-1}$ of the participant's body mass (Song and Sheykhlouvand, 2024). Participants began the test by pedaling at their maximum speed against the device's inertial resistance, after which a personalized load was added. Verbal encouragement was consistently provided throughout the 30-sec duration to ensure that participants maintained their maximum effort (Sheykhlouvand and Gharaat, 2024).

Blood sampling and analysis

To ensure consistency, participants were given clear instructions to visit the laboratory in the morning after overnight fasting and ensuring they had a sufficient sleep of 8 hours. These instructions were confirmed through a personal interview. Blood samples (10 mL) were then collected from the antecubital vein using plain evacuated test tubes. After allowing the blood to clot naturally at room temperature for 30 minutes, it was subjected to centrifugation at 1500 g for 10 minutes. The resulting serum layer was separated and stored at -20°C in multiple aliquots for subsequent analysis. The serum cortisol (CD creative diagnostics, USA, intra-assay CV = 9.32%] and testosterone (Eagle Biosciences, USA; intra-assay CV = 6.6%] levels were analyzed using ELISA kits (Sheykhlouvand et al., 2022; Gharaat et al., 2024).

COX training program

All participants engaged in 3 sessions of volleyball practice on Mondays, Wednesdays and Fridays in the afternoon for a duration of 100 to 120 minutes (i.e., 20-minute warm-up, 70 - 90 minutes of main training, and a 10-minute cool-down). Each volleyball training session included a range of technical and tactical drills, small-sided games and also emphasizing spiking, serving, and blocking drills. The players followed the same jump loads in each volleyball training session based on their respective positions. For example, the outside hitters completed approximately 45 serves, 110 spikes, and 70 blocks in each session. The participants in the experimental groups participated in two sessions of weekly COX training with varying rest distribution using two resistance (i.e., back squat and leg press) and plyometric exercises (squat jump and lunge jump) (Arazi et al., 2018). The players in the training groups performed 1 set of resistance training followed by 1 set of plyometric training with ~10 sec intervals for 4 sets as follows: back squat + squat jump and leg press + lunge jump. Each set of resistance exercise conducted with the intensity of 65% 1RM and the players during the plyometric exercise performed each jump with maximal effort. The number of repetitions progressively increased from week 1 to week 6. Table 2 presents the schedule for the training variables designed for players. With the guidance of a skilled strength and conditioning coach, the entire training program underwent thorough supervision to ensure that the participants adhered to appropriate training methods and exerted their utmost effort in each trial, maintaining a ratio of 1:4 (coach: athlete). The control group did not participate in any structured training programs including resistance, plyometric and or aerobic training.

Statistical analysis

The data are presented using the mean ± standard deviation (SD). Prior to performing any statistical comparisons, a normal distribution analysis was executed on the data using the Shapiro-Wilk test, and the homogeneity of variances was examined through Levene's test. To determine differences between groups, a two-factor (time [2] × group [3]) repeated-measures analysis of variance (ANOVA) was conducted, followed by a Bonferroni post-hoc test. The magnitude of training effects was assessed using the effect size (ES) with a 95% confidence interval (CI). Hedge's g was utilized to calculate the effect size for all measures. Based on the classification proposed by Hopkins et al. (2009), an effect size of < 0.2 was considered trivial, 0.2 - 0.6 was small, 0.6 - 1.2 was moderate, 1.2 - 2.0 was large, 2.0 - 4.0 was very large, and > 4.0 was nearly perfect. Individual percent changes (Δ% = (post - pre) / pre × 100) over time were calculated for each variable. Moreover, the individual residuals (Rs) based on percentage changes were computed by finding the square root of the squared discrepancy between the individual percentage change and the average percentage change for each variable that was analyzed (Tao et al., 2024). The significance level was set at 0.05. Statistical analyses were performed utilizing SPSS software (version 25.0, IBM Corp. Chicago, IL).

Table 2. Training variables in COX training*.

Week	Set type	Exercise intensity	Number of sets	Cluster × reps	Cluster rest (s)	Rest between sets (s)	Rest between RE and PE (s)
1	TS-COX	RE: 65% 1RM	4	1 × 10	0	90	10
	CS-COX	PE: maximal effort	4	2 × 5	30	60	10
2	TS-COX	RE: 65% 1RM	4	1 × 12	0	90	10
	CS-COX	PE: maximal effort	4	2 × 6	30	60	10
3	TS-COX	RE: 65% 1RM	4	1 × 14	0	90	10
	CS-COX	PE: maximal effort	4	2 × 7	30	60	10
4	TS-COX	RE: 65% 1RM	4	1 × 12	0	90	10
	CS-COX	PE: maximal effort	4	2 × 6	30	60	10
5	TS-COX	RE: 65% 1RM	4	1 × 14	0	90	10
	CS-COX	PE: maximal effort	4	2 × 7	30	60	10
6	TS-COX	RE: 65% 1RM	4	1 × 16	0	90	10
	CS-COX	PE: maximal effort	4	2 × 8	30	60	10

*back squat + squat jump and leg press + lunge jump with a 3-minute rest between them. RE: resistance exercise, PE: plyometric exercise. CS-COX: cluster sets complex, TS-COX: traditional sets complex.

Results

Every participant in this research exhibited absolute adherence, achieving a perfect success rate of 100%. Furthermore, no incidents of injuries were reported in connection with the utilized training and testing interventions. At the pre-intervention stage, the experimental groups did not exhibit any significant differences in the variables (group effect, p > 0.05). Nevertheless, the post-intervention results demonstrated a significant group by time interaction (p = 0.001), which indicates that there were significant differences in outcomes between the CON and the training groups. Additionally, from pre- to post-intervention, the CON group who only participated in the volleyball training, did not exhibit any significant alterations in their measured variables.

After the completion of the 6-week training period, there were significant changes in the CMVJ (p = 0.001), SPJ (p = 0.001) and T-test CODS (p = 0.001) for the CS-COX and TS-COX groups. There was a significant group × time interaction in the CMVJ (p = 0.031, ES = 0.36, 95% CI = -0.65 to 1.36), SPJ (p = 0.038, ES = 0.06, 95% CI = -0.92 to 1.04), and T-test CODS (p = 0.046, ES = -0.60, 95% CI = -1.61 to 0.43), indicating greater training effects for the CS-COX group than the TS-COX group following the 6-week intervention (Table 3). Comparison of the individual percent changes indicated significantly greater gains in the CMVJ (p = 0.046), SPJ (p = 0.034) and T-test CODS (p = 0.047) for the CS-COX group compared to the TS-COX group, with lower inter-subject variability in response to training intervention (Figure 2).

Both the CS-COX and TS-COX groups demonstrated moderate significant gains (p = 0.001) in the maximal strength performance (Figure 3). Specifically, similar individual percent changes in the 1RM leg press (CS-COX: 9.8% ± 2.3%, Rs in individual percent change = 1.90; TS-COX: 9.7% ± 3.3%, Rs in individual percent change = 2.70), and 1RM back squat (CS-COX: 10.9% ± 2.0%, Rs in individual percent change = 1.72; TS-COX: 10.9% ± 2.6%, Rs in individual percent change = 2.30) were observed following the 6-week training.

The peak power output increased significantly (p = 0.001) after the CS-COX and TS-COX training intervention (Figure 4, A). The CS-COX group demonstrated a large significant increase in the peak power output achieved during the Wingate anaerobic test in response to the 6-week training period, which was significantly (F = 7.31, p = 0.03, ES = 0.72, 95% CI = -0.29 to 1.73) greater than the moderate increase demonstrated by the TS-COX group (12.2% ± 1.9%, Rs in individual percent change = 1.28 *versus* 8.5% ± 4.4%, Rs in individual percent change = 3.48). Conversely, both the CS-COX (10.8% ± 3.4%, Rs in individual percent change = 2.04) and TS-COX (10.8% ± 5.8%, Rs in individual percent change = 4.37) groups demonstrated moderate significant gains (p = 0.001) in the mean power output (Figure 4, B), without significant differences between them (p = 0.963).

After the completion of the 6-week training period, both the CS-COX and TS-COX groups demonstrated significant (p = 0.001) small increases in testosterone concentrations (Table 3). No group by time interaction was observed for the changes in testosterone concentrations (F = 2.6, p = 0.145) (Figure 5, A). When examining the serum cortisol responses to training intervention, the CS-COX group displayed a moderate significant (F = 13.4, p = 0.008, ES = -0.30, 95% CI = -1.27 to 0.70) decrease compared with the small significant decrease displayed by the TS-COX group (Table 4 and Figure 5, B).

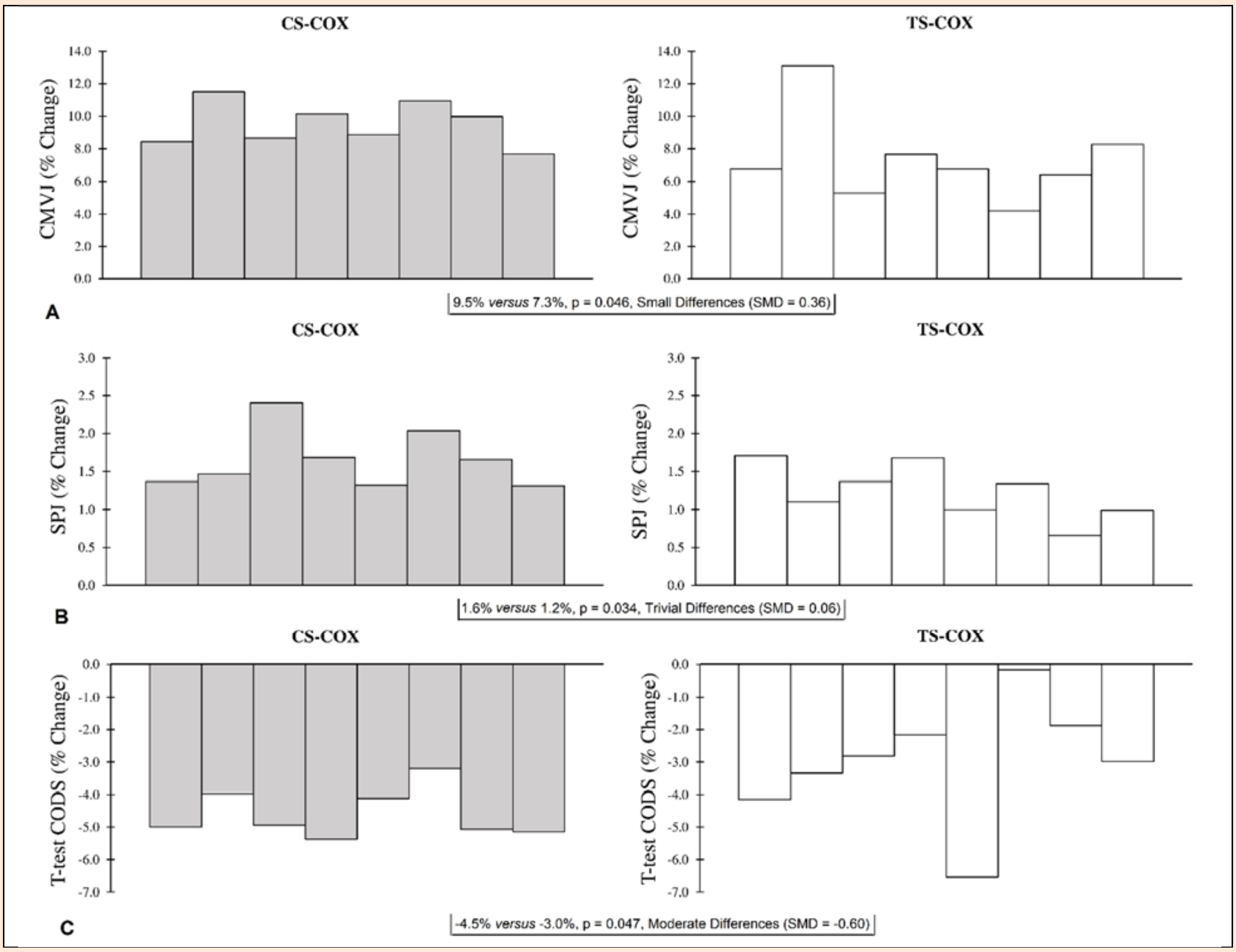

Figure 2. Individual percent change in physical performance after training intervention for the training groups. CS-COX: cluster sets complex, TS-COX: traditional sets complex, CMVJ: countermovement vertical jump, SPJ: spike jump, CODS: change of direction speed.

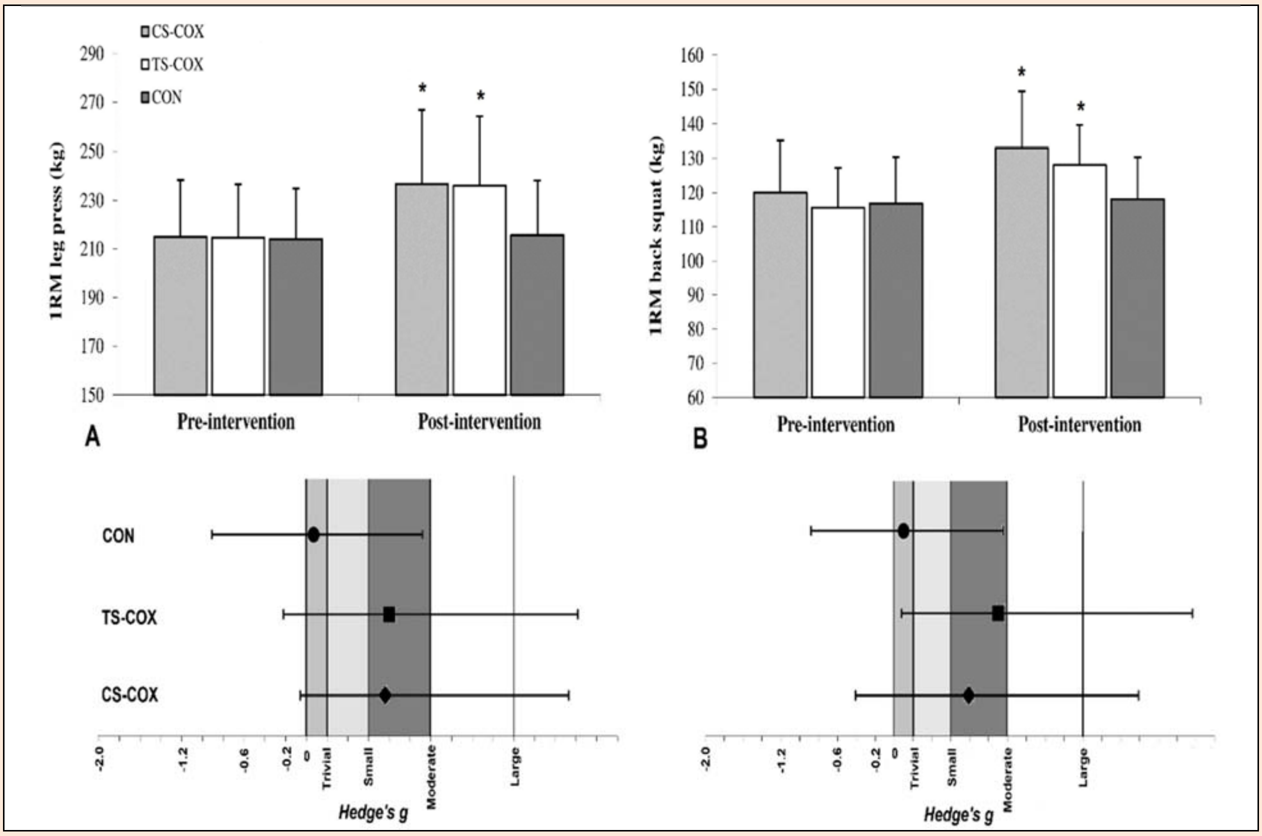

Figure 3. Pre to post-intervention changes in strength performance (mean ± SD). *Significant differences compared with Pre and CON ($p < 0.05$). CS-COX: cluster sets complex, TS-COX: traditional sets complex, CON: control.

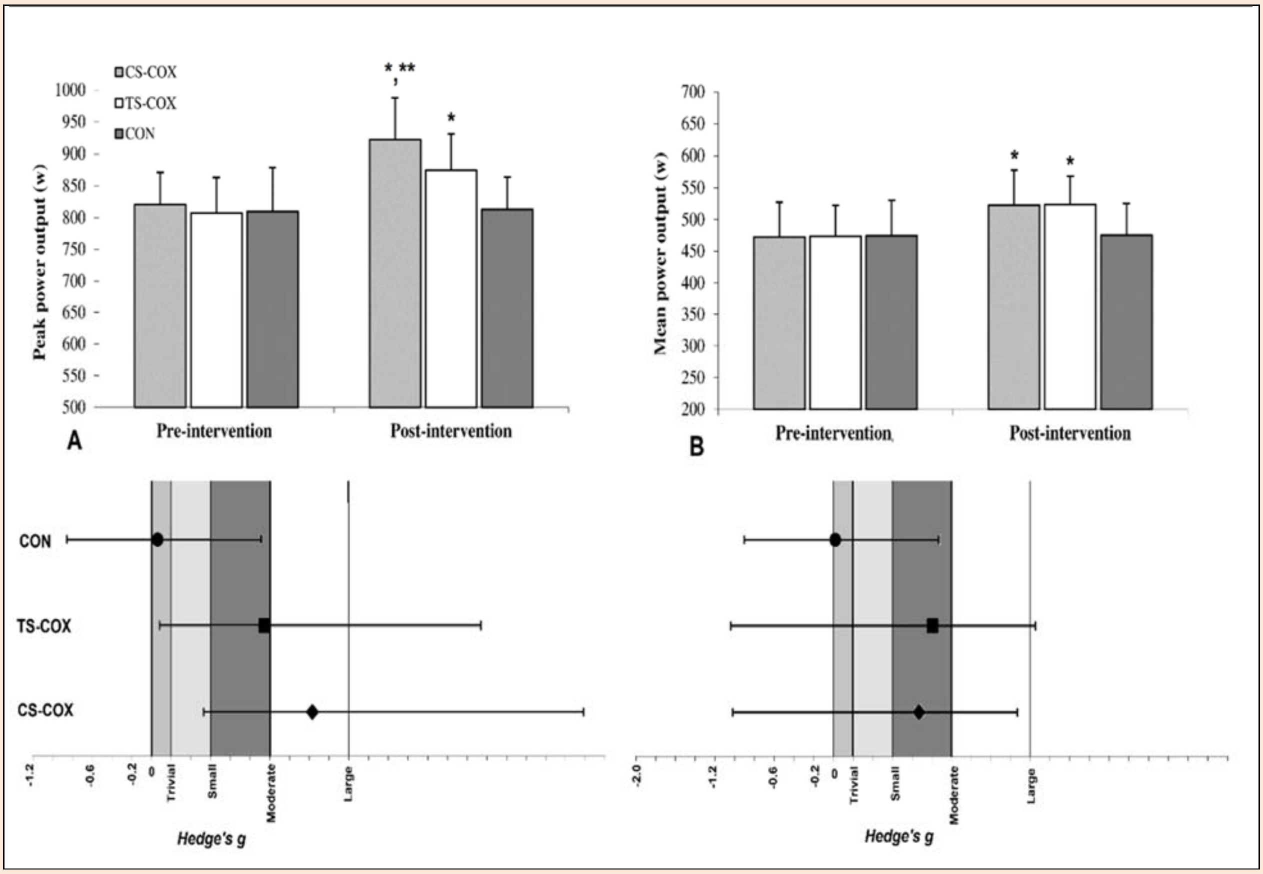

Figure 4. Pre to post-intervention changes in power performance (mean ± SD). *Significant differences compared with Pre and CON ($p < 0.05$). **Significant differences compared with TS-COX ($p < 0.05$). CS-COX: cluster sets complex, TS-COX: traditional sets complex.

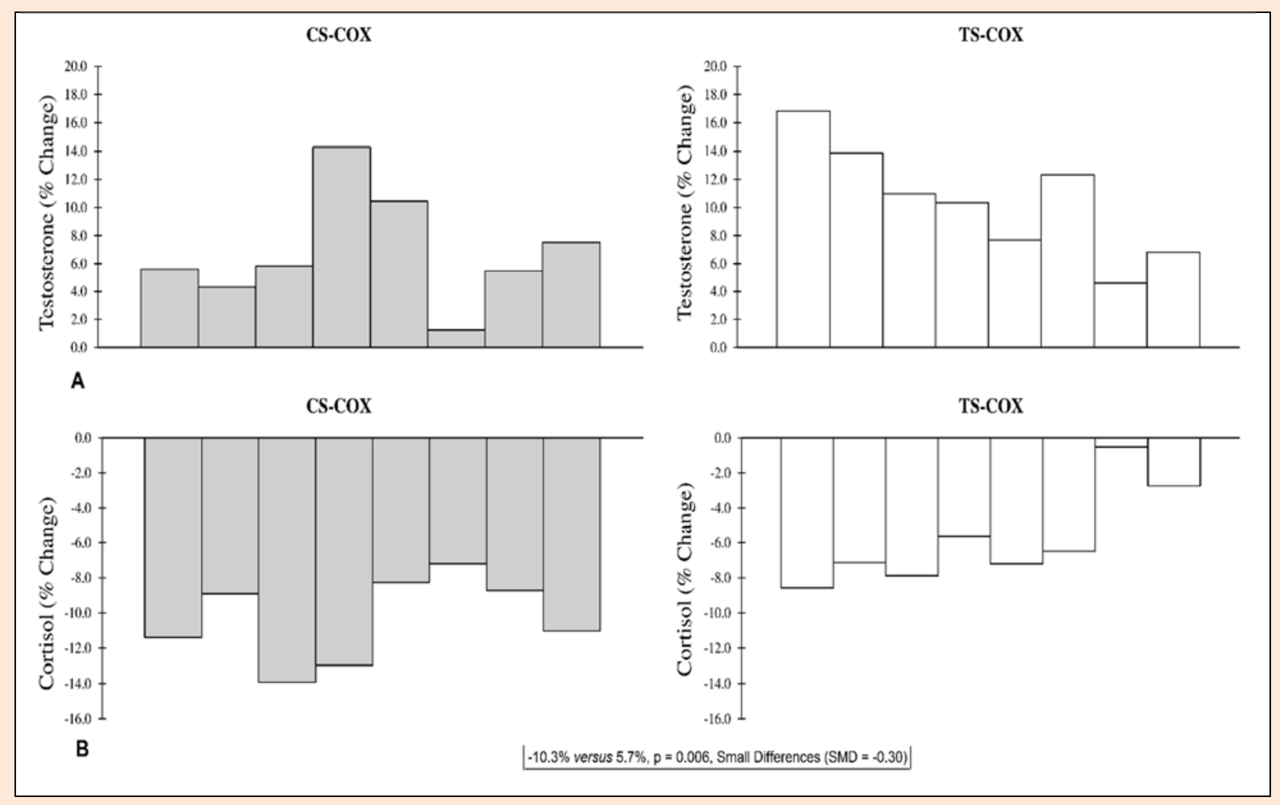

Figure 5. Individual percent change in resting hormonal levels after training intervention for the training groups. CS-COX: cluster sets complex, TS-COX: traditional sets complex.

Discussion

Although COX training has been recommended to induce more adaptations in athletes (Arazi et al., 2014), the impact of cluster sets COX training on physical performance adaptations in male volleyball players following a 6-week training intervention has not been thoroughly investigated. This study aimed to explore the effects of a 6-week COX training with different set configurations (cluster sets vs. traditional sets) on jumping ability, power output, strength, and hormonal adaptations in young male volleyball players. The results of this study revealed that a 6-week CS-COX training not only induced greater adaptive responses in bio-motor ability and peak power performance but also led to lower cortisol levels than the TS-COX following the training period. Conversely, both the CS-COX and TS-COX groups demonstrated similar enhancements in maximal strength, mean power output, and resting testosterone concentrations following the training intervention.

Previous research has shown that enhancing jumping ability (i.e., CMVJ) and CODS (i.e., T-test and Illinois) following COX training can be achieved through improvements in neuromuscular adaptations, better synchronization of motor unit firing, increased coordination levels, and greater recruitment of motor units resulting from combined plyometric and resistance training (Watts et al., 2012; Arazi et al., 2014; Berriel et al., 2022), as supported by our findings. The superior adaptive responses in these physical fitness components following CS-COX training may be linked to higher motor neuron excitability and reflex potentiation compared to other training modalities (Ishak et al., 2021). Evidently, cluster sets integrated into plyometric and resistance training have the potential to affect power generation capabilities (Asadi and Ramírez-Campillo, 2016; Arazi et al., 2018), thereby enhancing jumping ability and horizontal speed movements to improve an athlete's overall performance. Conversely, prior research has proposed that incorporating cluster sets into a training routine is particularly beneficial for targeting enhancements in power generation capacity in resistance and power training (Nagatani et al., 2022). The basis for this suggestion lies in the effectiveness of brief inter-repetition or intra-set rest periods in enabling the partial replenishment of PCr stores and in sustaining or improving movement speed throughout a training session (Tufano et al., 2016). Indeed, it seems that incorporating cluster sets (i.e., a 30-sec rest interval between repetitions) led to notably increased peak velocities in acute performance (Haff et al., 2008). Integrating cluster sets into a training regimen can enhance training specificity for power development due to higher training velocities (Tufano et al., 2016; Arazi et al., 2018), ultimately enhancing performance in high power movements such as CMVJ, SPJ, and T-test CODS tasks measured in the current study.

The outcomes of this investigation are consistent with previous studies that have demonstrated that a combination of resistance and plyometric training can have a significant impact on enhancing strength performance (Watts et al., 2012; Arazi et al., 2014). This enhancement can be attributed to the augmentation of motor neuron excitability, the increase in motor unit firing frequency, and the rise in efferent motor drive following the training, along with the induction of muscle hypertrophy due to the training (Ebben, 2002). Similar to our findings, Arazi and collagenous

(2018; 2021) reported that cluster sets during resistance training induced similar effects on strength gains when compared with traditional sets. While cluster sets are often advised for power development, traditional sets are typically considered more appropriate for enhancing maximal strength. In relation to COX training, it was the first study that compared CS-COX training versus TS-COX training in volleyball players with aiming to compare the magnitude of training effects on strength gains. The study demonstrated that when resistance and plyometric training methods were combined in a single session, there were moderate enhancements in leg press and back squat strength gains for both interventions. It was observed that there were no significant differences in the adaptive changes of neuromuscular and also other mechanisms (i.e., similar resting testosterone adaptations) associated with strength gains following the cluster sets and traditional sets configurations (Arazi et al., 2018). Additionally, the increases in muscular hypertrophy resulting from training may serve as another mechanism for facilitating adaptive changes in strength performance (Li et al., 2019). It appears that the configuration of set structures does not significantly influence the extent of gains achieved after the training intervention (Davies et al., 2021).

This investigation was the primary examination to determine the impact of a 6-week COX training regimen with variations in set structure on the Wingate anaerobic power test in male volleyball players. The CS-COX group experienced a large increase in peak power output compared to the moderate increase observed in the TS-COX group after the 6-week training period. Conversely, both the CS-COX and TS-COX groups showed similar moderate training effects on mean power output. More adaptations in peak power output following the CS-COX training could be due to more adaptive changes in the ATP-PCr metabolic pathway. In fact, an elevation in the quantity of rest intervals could potentially improve recovery by preserving PCr and ATP reserves, as well as enhancing metabolite clearance (such as lactate accumulation) (Haff et al., 2008; Forbes and Sheykhlouvand, 2016; Gharaat et al., 2020) This, in turn, may enable a greater availability of substrates, facilitating the maintenance of movement velocity throughout all sets in COX training leading to more adaptive change in short-term (i.e., 5 sec) maximal effort trials by athletes (Tufano et al., 2016).

However, there is a lack of conclusive evidence regarding the superiority of any particular training method in relation to physiological variables associated with gains in mean power output. It is crucial to maintain consistent power production during the 30-sec Wingate anaerobic power test and a combination of resistance and plyometric training with differing in rest distribution through the training program did not induce superior outcomes and produced the same (i.e., moderate ES) training effects on power production leading to similar gains in mean power output achieved during the Wingate test. Indeed, cluster sets loading is appropriate for bouts of short-duration, such as those involving jumping ability (Jusoh et al., 2019). It appears that performance attributes requiring sustained force production and involving other metabolic pathways, such as glycolytic to oxidative, were not significantly impacted by this type of training (Haff et al., 2008). Nevertheless, it is important to note that this study represents the initial investigation, and additional research is necessary to elucidate the adaptations in power performance when examining different cluster sets distribution in athletes using the Wingate anaerobic test.

Resting testosterone concentrations are commonly associated with anabolic enhancements when accompanied by decreases in resting cortisol concentrations (Staron et al., 1994). Consistent with previous research on hormonal concentrations during cluster sets loading (Arazi et al., 2018), our study revealed that both the CS-COX and TS-COX groups experienced similar increases in testosterone levels after the 6-week training period. The potential mechanisms responsible for facilitating this adaptation in exercise-induced serum testosterone levels in individuals may arise from traditional enhancements in luteinizing hormone pulsatility or production (Kraemer and Ratamess, 2005). The activation of the endocrine system during exercise can potentially initiate adaptive processes in skeletal muscle cells, resulting in an augmentation of contractile protein levels (Kraemer and Ratamess, 2005). Notably, testosterone is widely recognized as the primary promotor of muscle development and the subsequent enhancement of muscular strength following training (Vingren et al., 2010). Furthermore, it is worth noting that both training groups exhibited small but significant enhancements in testosterone levels. This suggests that incorporating either traditional or cluster sets into a training routine can lead to the establishment of a favorable hormonal profile during rest periods. The study findings also indicated that both CS-COX and TS-COX training programs resulted in similar adaptations in testosterone levels and also strength gains which describe the positive relationship between testosterone concentrations and strength gains following CS-COX and TS-COX training regimen (Tufano et al., 2019).

It appears that to control long-term training stress, alteration of the resting cortisol levels is an important indicator to manage training loads (Kraemer, and Ratamess, 2005). Collectively, when the training load is reduced, resting cortisol levels decrease and often return to normal levels (Kraemer and Ratamess, 2005). In the present study, both training groups showed a decrement in resting cortisol levels; however, the CS-COX group displayed a greater decrease in response to training. It suggests that the incorporation of cluster sets during training interventions may create a favorable environment not only for improving power performance but also for reducing the metabolic stress associated with training compared with the traditional training sets (Arazi et al., 2018; Tufano et al., 2019). The factors that influence cortisol levels are complex and multifaceted. In addition to changes induced by exercise from our study protocol, various nutritional, physiological, psychological, environmental, and lifestyle elements - including sleep, diet, alcohol consumption, emotional states, dominance, and mental fatigue - can also impact the adaptive responses of cortisol levels to training (Kraemer and Ratamess, 2005). Notably, the findings of this study indicated that CS-COX training may have a significant effect on catabolic hormones, extending beyond the physiological aspects that influence cortisol responses during training. Since the strength adaptations between the CS-COX and TS-COX configurations were similar, these findings suggest that a brief rest within the single set can be utilized as a strategy to induce less physiological stress and fatigue (Api et al., 2023) while achieving similar gains in testosterone concentration and also strength performance.

This study utilized a particular approach to analyze the results by evaluating individual adaptive responses to COX training through cluster sets and traditional sets, addressing shortcomings noted in prior research involving COX training or cluster set configurations (Watts et al., 2012; Arazi et al., 2014; 2018; Berriel et al., 2022). Previous studies predominantly concentrated on reporting the mean and standard deviation of training groups, along with the magnitude of effects quantified by Δ% or ES. However, such methods of presenting results may not be appropriate for team sports, where the varying fitness levels of individual players can significantly influence the overall performance of the team (Tao et al., 2024). Analyzing the individual Rs in Δ% for physical performance assessments is crucial for understanding the extent of change in each player and their respective adaptive responses to training (Tao et al., 2024). Additionally, the calculation of ES and Δ% are important factors that should be included in the results of the study, as highlighted in previous research (Arazi et al., 2014; 2018; Berriel et al., 2022). In this investigation, the individual Rs in Δ% was reported as a method to illustrate the consistency of adaptive changes among players following the training intervention. Our findings indicated that volleyball players in the CS-COX group demonstrated lower Rs in Δ% for physical performance, and hormonal adaptations when compared to the TS-COX group. This finding suggests that incorporating a short rest duration (i.e., 30 sec) within a single training set resulted in greater consistency in adaptations among volleyball players. However, it is important for subsequent research to manage other pertinent factors that may impact the adaptive responses to training, including sample size, factors influencing trainability, and the season's timing.

The current research presents several methodological limitations that warrant further examination. Firstly, the study's statistical power has been affected by the relatively small sample size of athletes (n = 8 for each group). Nevertheless, a priori power analysis has been performed, demonstrating that this sample size is adequate for achieving sufficient statistical power (Berriel et al., 2022). Secondly, the observation period was relatively brief; however, prior research has suggested that this duration is appropriate for eliciting adaptations in athletes (Arazi et al., 2021). Thirdly, the results of this study are specifically relevant to trained male volleyball players during preparation phase. Additional research is necessary to determine whether these findings can be generalized to female players and to volleyball athletes across various age groups and fitness levels. Finally, it would have been beneficial to include various configurations of cluster sets to better understand optimal rest intervals within a set compared to other rest durations. To validate our findings, future studies should consider these variables. Given these limitations, we recommend that subsequent research focus on longer-term studies, different athletic populations, or other factors that may influence the efficacy of COX training.

Conclusion

The findings of the percent study suggest that a 6-week COX training is an effective method to induce small to large gains in physical and physiological performance, as well as small to moderate changes in resting hormonal concentrations in young male volleyball players. Additionally, the incorporation of a brief rest interval (i.e., 30 sec) within a single set of training known as "cluster sets" not only induced greater adaptive changes in physical performance and peak power output but also produced greater decrements in resting cortisol levels than the configuration of the traditional sets. In addition, both the training groups indicated similar gains in strength performance, mean power output and resting testosterone levels following the training intervention. In light of these results, it is recommended that coaches, and trainers in the field of volleyball employ cluster sets during COX training sessions to produce more adaptive changes in bio-motor ability, peak power output and cortisol adaptations with better consistency and homogeneity in adaptations within the players.

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Key points

- COX training is a suitable training approach for adequately stimulating mechanisms involved in small to large training adaptations in volleyball players' physical performance.
- Incorporating cluster sets in COX training is more effective than traditional sets for maximizing physical performance attributes and peak power output, as well as decrements in resting cortisol levels.
- Both the training approaches result in similar benefits in the maximal strength gains, mean power output and changes in serum testosterone concentrations.

AUTHOR BIOGRAPHY

Bo RONG
Employment
Central South University of Forestry and Technology, Changsha, 410004, Hunan, China
Degree
PhD
Research interests
Physical education and athletic performance
E-mail: T20071571@csuft.edu.cn

Chen XIU
Employment
School of Athletic Performance, Shanghai University of Sport, Shanghai, 200438, China
Degree
MSc
Research interests
Physical education, Athletic training
E-mail: xiuchen0911@163.com

✉ **Chen Xiu**
School of Athletic Performance, Shanghai University of Sport, Shanghai, 200438, China